PRIVATE GENERATING PLANT

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INCLUDING EMERGENCY AND STAND-BY SYSTEMS

Dealing with Generating Plant and Emergency Lighting and Power Systems for Factories, Hospitals, Cinemas, Theatres, Institutions, Offices, Stores and Country Houses, with Notes on Installation, Operation and Maintenance

BY

"PROTON"

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PREFACE

ALTHOUGH the completion of the Grid scheme has rendered electrical power accessible to thousands of country houses and works which were previously without this facility, there is still a very definite demand for various types of private electric generating plant both large and small.

There is the case of the manufacturing works where steam is required in some stage of the manufacturing process. In such circumstances it is often an economy to use high pressure steam for driving the steam electric generating set, leaving the low pressure steam (after it has passed through the engine or turbine) available for processing.

There are also cases where, owing to the special geographical conditions, the charge which the local electricity supply company will have to make for supplying power to works, renders it an economic proposition to install a Diesel electric generating set.

In addition to these two groups, there are many works already on the Grid supply, where it is deemed advisable to have a private generating plant available as a standby in case of a temporary dislocation of the public supply.

Many public buildings, particularly hospitals, theatres and cinemas find that it is of vital importance to have an alternative source of supply on the premises. Although private generating plant is not the only method of obtaining such an alternative supply, it does in certain cases offer the most satisfactory solution to the problem.

There are, of course, definite Home Office Regulations stipulating that in every theatre and cinema there shall be an adequate number of safety or emergency lights which must be fed from a source entirely independent of that of the main auditorium. There are, however, many other types of public buildings, notably hospitals, railway stations, aerodromes and hotels, where, owing to a sense of civic responsibility on the part of owners, architects and

engineers, an alternative source of lighting is insisted upon, though it is not compulsory under the law.

The above facts provide the reason for the publication of the present book. All the chief types of generating plant of small and medium sizes have been described in detail.

Several diagrams of automatic and semi-automatic lighting sets are included, and separate chapters have been devoted respectively to the subjects of installation and maintenance.

Although wind-driven generators have not yet been used very widely in this country, there are signs of increasing interest in this subject. Up to the present very little information has been available on this aspect of power generation, and it is believed, therefore, that the information given in Chapter VI "Wind-Driven Lighting Plant" will be found of wide interest not only to readers who are contemplating the erection of a wind-driven lighting plant, but also to electrical engineers who wish to extend their knowledge of this particular aspect of the subject.

We have pleasure in acknowledging our indebtedness to the makers whose products are illustrated and described.

In particular, we would mention Messrs. Ruston & Hornsby, Petters, Ltd., Stuart Turner, R. A. Lister & Co., Ltd., Crompton Parkinson, Ltd., Flather & Co., Ltd., Kohler Co., Ltd., Exide Co., Ltd., Nife Batteries, Ltd., and Joseph Lucas, Ltd., to whom we are indebted for many of the technical facts and data in the book.

It is hoped that this practical survey of the various types of generating plant now available will prove both interesting and useful to electrical engineers, consultants, electrical contractors and students, who wish to add a knowledge of up-to-date practice to the theoretical groundwork provided by their studies.

A. J. C.
E. M.

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PRIVATE GENERATING PLANT

CHAPTER I

GENERATING PLANT FOR FACTORIES AND WORKS AND ISOLATED BUILDINGS

FOR the vast majority of factories, public institutions and private houses, the electric grid provides the most convenient and economical source of power. There are, however, still a large number of cases where private generating plant must receive serious consideration. Among these are the following: in the works or factory where process steam is required; in factories and works, public institutions and hospitals, farms, and private houses situated in districts not yet supplied from the electricity grid system; and finally in buildings where an emergency standby supply is considered advisable, but not available from outside sources. In the present chapter, the various systems of private generating plant are outlined.

Motive Power.

The type of motive power adopted for a private generating plant will depend partly on the size of the plant and partly on the individual circumstances. Before putting in hand a large power scheme the following items should receive careful consideration prior to deciding what type of prime mover is to be used.

1. Maximum load and fluctuations of load.

2. Possibility of future increase of load.

3. Cost of fuel delivered, steam coal, gas coal, diesel oil, etc., per brake horse-power produced.

4. Space available, and the available means of transport for fuel to the plant.

5. Storage costs for fuel, depending on the rates and rateable value of buildings, etc.

6. Capital cost of engines and boilers, gas engine and producer, or engine plant.

7. Depreciation, maintenance and repair costs, and cost of labour feeding and supervising the plant.

8. Possibility of utilising waste heat; often the deciding factor.

9. Any restrictions of the local authority with respect to noise and smoke emission, etc.

10. Availability of water for boilers, etc.

Possibilities of Water Turbines.

If there is a good water supply, free from restrictions, available, it may be possible to use this to provide a cheap source of power, by means of a water turbine. In the case of a plant situated in a valley at the foot of rocky hills the water will collect rapidly and a dam capable of containing a comparatively large volume of water would be necessary, but where the hills are boggy or have a natural lake at a high level it is not so essential to construct a large reservoir. A water power scheme should not, however, be lightly undertaken by persons not possessing special knowledge of such work.

Steam Engine or Turbine Drive.

Where a large plant is required, as for a works or a large estate, a steam engine or turbine is a suitable means of drive if coal can be delivered on site at low cost, and a considerable saving can sometimes be effected by using an engine or turbine working in conjunction with process plant which requires steam or
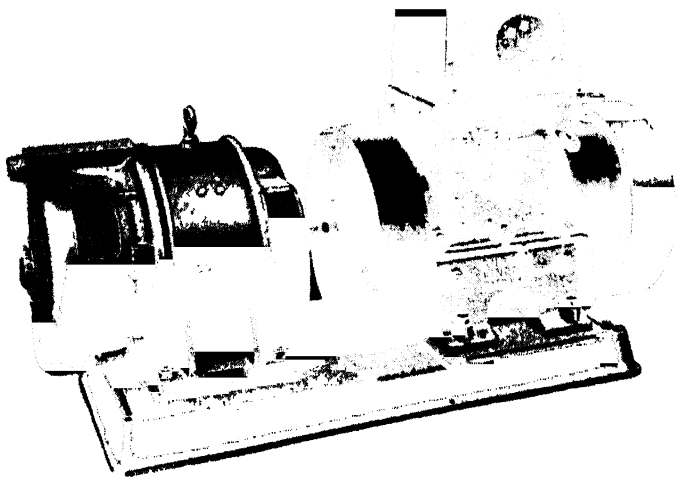
FIG. 1—10 kW OIL-ENGINED GENERATING SET.
(*Ruston & Hornsby, Ltd*)

boiling water. In a large works the main driving engine may be capable of supplying the extra power necessary for driving a lighting dynamo from a line shaft. In this case, if a battery is not to be used, it is usually necessary to install a small separately driven pilot dynamo to supply lights when the main engine is not running.

Gas Engines.

Gas engines working from town's gas require no fuel reserves and may be a sound proposition where gas can be supplied at a suitable pressure. If some form of waste fuel, such as sawdust or gases are available in sufficient amount it may be worth while to utilise this in a gas producer, providing there is sufficient space to
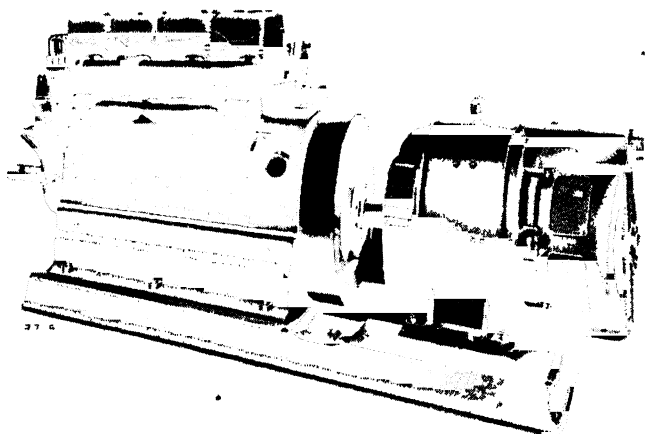
FIG 2 —27 5 kW OIL-ENGINED GENERATING SET
(Ruston & Hornsby, Ltd)

install the necessary plant and associated scrubbers, etc , and that the cost of the labour necessary to attend to the plant is not too high.

Crude Oil or Diesel Engines.

Crude oil or diesel engines are very common for driving dynamos of about 5 kW. or over. These

Fig 3.—Petter Super-scavenge Diesel Engines Driving Crompton-Parkinson and Lancashire Alternators Installed in the Power House at Diyatawa for the Electric Lighting of Three Towns in Ceylon

engines are usually started up by compressed air from a receiver which is recharged from a compressor driven by the engine when it starts running. To save time in the event of the air receiver becoming exhausted due to bad starting at any time, it is useful to have a small standby compressor driven by a separate petrol engine, or electric motor where a standby or battery supply is available.

Petrol Engine Sets.

Below 5 kW., petrol engines, or paraffin engines which start up on petrol, are usually employed. They are convenient and simple and require fewer accessories than crude oil plants. They may be started up by cranking the engine, or means may be adopted to run the dynamo as a motor from the battery, if one is fitted, until the engine fires and takes control.

Wind-driven lighting plant is dealt with in Chapter VI.

Size of Engine.

The engine installed should be large enough to drive the dynamo for long periods on full load. Should the engine speed fall on heavy load the voltage of the dynamo will be reduced when a high voltage is most necessary, and it should be remembered that the engine power may fall due to poor fuel or inadequate maintenance. For a dynamo having a capacity up to about 3 kW. the brake horse-power of the engine should be about twice the kW. output of the dynamo. On a larger plant the brake horse-power =

$$\frac{\text{kW. output}}{0{\cdot}746 \times \text{Efficiency of dynamo.}}$$
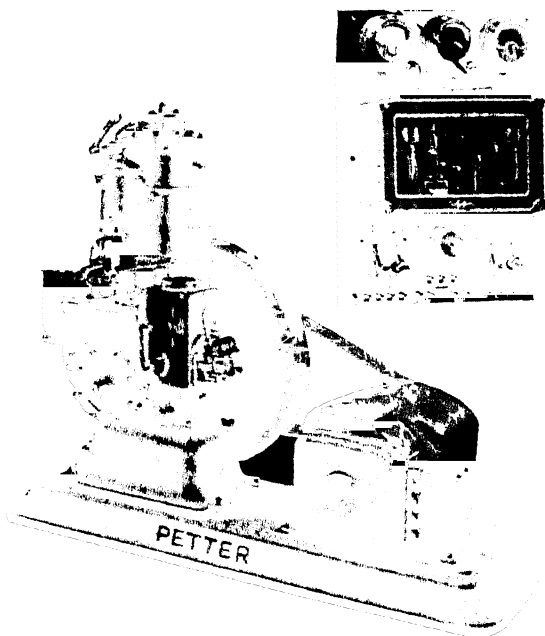
FIG. 4.—FULLY AUTOMATIC SET WITH DIESEL ENGINES FOR 2·5 TO 5 kW.
(*Petters, Ltd.*)

A 30 kW. dynamo having an efficiency of 90 per cent. would require $\frac{30}{0{\cdot}746 \times 0{\cdot}9} = 44{\cdot}9$ brake horse-power for driving. Where the dynamo is driven through a belt the brake horse-power of the engine should be about 10 per cent. higher than with a direct drive to allow for losses in power transmission. A lower speed engine is likely to last longer and to require less maintenance than a high-speed engine, other things being equal.

Generator.

For a large works an alternator is often adopted so that squirrel-cage motors of simple construction and low cost can be used, but in smaller premises the private generating plant is usually D.C. This is slightly safer than A.C. and has certain advantages in that speed regulation of motors can easily be obtained; the D.C. supply is suitable also for such apparatus as

FIG. 5—1 kW, 50-VOLT STATIONARY GENERATING PLANT WITH 2 B.H.P. STUART PETROL ENGINE
(*Stuart Turner Ltd.*)

magnetic chucks, etc., and if required a battery can be used to provide a standby supply for lighting and small power purposes when it would not be economical to run the engine. Generators used for factory and other plant where batteries are not used should have a compound field winding so that the voltage can be maintained on load without frequent adjustment of the field regulator.

Large works may use a voltage as high as 250 or 500 volts, especially if the plant is scattered, in order to reduce the amount of copper required for the cables. In some cases a 3-wire system is used in the works, giving a supply at half voltage for lighting and small motors and full voltage for the larger motors, with static or rotary balancers for dealing with any out of balance current which may pass along the neutral.

Where the load varies considerably, two or more generators may be employed in parallel or feeding separate circuits to avoid uneconomical running which would be experienced if a generator were run for lengthy periods on part load.

For a smaller works or country mansion 100 volts is sufficient for lights and motors, and has the advantage of being safer and requiring a battery of fewer cells for standby purposes; whilst a small private house may adopt a supply voltage of 50 volts for lighting and small domestic appliances.

Battery.

Where a battery is used this should be of ample capacity if the life of the battery is to be prolonged and maintenance costs are to be kept low. For a private house the battery should be capable of supplying about ten hours full lighting load on one charge, plus any heating load which may be required at the same time. The battery should be placed in a separate well-ventilated room to allow the escape of fumes.

With a battery and dynamo outfit special means must be adopted, as described later, to keep the supply voltage steady, since the voltage of each cell may vary between 1·8 volts when discharged and 2·1 volts when

fully charged. The dynamo must be capable of supplying 2·7 volts per cell in order to charge the battery or else a separate booster must be fitted to supply the extra volts necessary to bring the battery up to full charge For a 50-volt supply the number of cells needed to maintain the voltage when fully
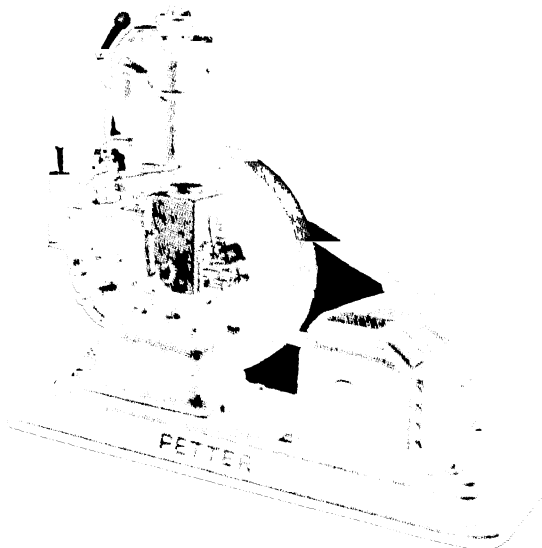
FIG 6 — DIESEL ENGINE BATTERY-CHARGING SET
(*Petters, Ltd*)

charged is $\frac{50}{2·1} = 24$, whilst the number of cells necessary when the battery is practically discharged is $\frac{50}{1·8} = 28$. For fully charging a 28-cell battery the dynamo voltage must be $28 \times 2·7 = 75$ volts, and the dynamo should be capable of steady operation between 50 and 75 volts on load.

Operation of Dynamos in Parallel.

When compound dynamos are operated in parallel an extra connection must be made between the generators to equalise the current in the series field windings. If this were not fitted and the speed of one dynamo fell slightly due to belt-slip, faulty engine governor or other cause, the resulting fall of generated voltage in this machine would cause extra load to be thrown on
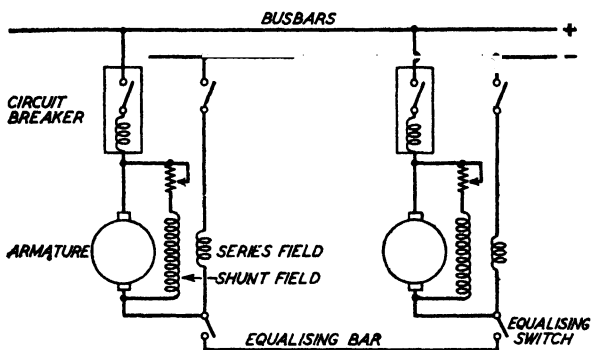
FIG. 7.—COMPOUND DYNAMOS IN PARALLEL.

to the other machine or machines. The reduced load in the series field of the slower dynamo would cause still further fall of generated voltage in this machine and eventually this machine might be operating as a motor, with a risk of the other plant being overloaded or the supply being cut off by the operation of the overload releases of the heavily loaded plant. The connections for compound dynamos in parallel are shown in Fig. 7. When connecting a dynamo to the live busbars the equalising switches must be closed first and the voltage of the dynamo adjusted practically equal to the busbar voltage before paralleling by closing

the main switches. The equalising switch should be opened last when taken a machine off the bus-bars.
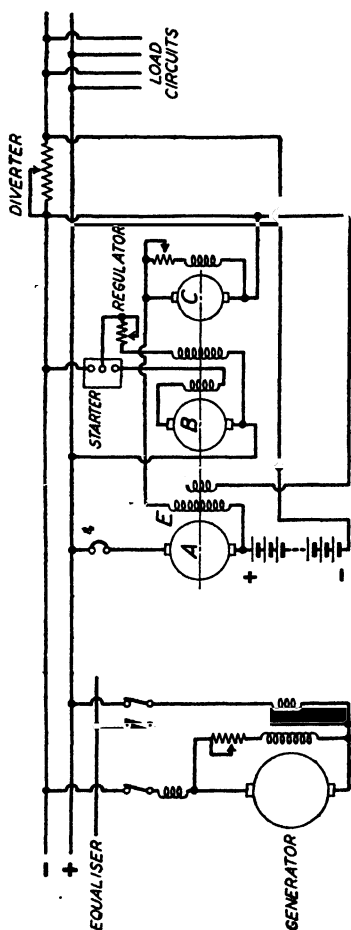
Fig. 8.—Highfield Automatic Reversible Booster.

Boosters.

As mentioned previously, one method of supplying the extra voltage necessary to charge a battery is to use a booster. This is a low voltage generator driven by electric motor or other source of motive power and is connected in series with the dynamo. The booster may be hand controlled or automatic in operation. Fig. 8 indicates the connections of one type of automatic booster consisting of the booster generator *A*, an exciter *C*, and a constant speed compound motor *B*

coupled together. The laminated field of the booster generator is compound wound and this machine is designed so that the voltage generated is exactly equal to the voltage applied to its field coils.

The shunt windings *E* and the series windings *D* are arranged so that with normal load on the busbars the sum of the battery and booster E.M.F.s are equal to the busbar voltage and the battery floats across the busbars. On heavy load the series winding *D* increases the booster voltage, and if the battery voltage is lower than that of the exciter the direction of current flow through *E* will cause the shunt windings to assist the series windings. Should the battery voltage be high the exciter will motor from the battery and the two fields will be in opposition. Under all conditions the battery current is independent of battery voltage, the battery discharging on heavy load and charging on light load. This method can be used for a 3-wire D.C. circuit, the booster being coupled to the same shaft as the balancer. A booster can also be used to raise the voltage to compensate for voltage drop on a heavily loaded feeder.

Rotary Balancer.

On a 3-wire D.C. circuit the load between one outer and neutral may be much heavier than between the other outer and neutral. In order to maintain the voltage on each circuit as near as possible at normal value a rotary balancer is often used.

This consists of two identical machines direct coupled together, with the armature of each machine connected between one outer and neutral as in Fig. 9. The field windings of each machine are usually
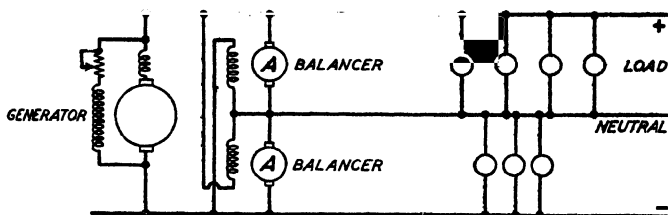
FIG. 9.—ROTARY BALANCER ON THREE-WIRE D C. CIRCUIT.

connected across the opposite circuit to the armature. If the voltage of, say, the positive circuit falls due to heavy load the field of machine B is reduced whilst that of machine A is increased. Machine B increases its speed as a motor and takes more load from the lightly loaded circuit, and this reduces the negative to neutral voltage. Machine A generates a higher voltage by reason of its higher speed and increased field, and supplies current to the positive circuit to increase the voltage. Under balanced load conditions both machines run idly as motors.

Static Balancers.

These can deal with an out of balance current of 25 per cent. or so, but cannot raise the voltage on the heavily loaded side as in the case of a rotary balancer;
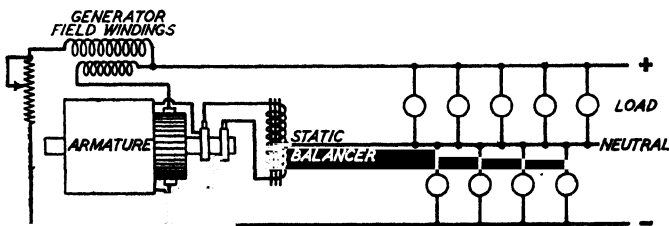
FIG. 10.—STATIC BALANCER ON THREE-WIRE D C. CIRCUIT.

they have, however, no friction losses. The static balancer consists of a choking coil with its mid-point connected to the neutral of the 3-wire supply, the ends of the choking coil being connected to brushes on two slip-rings connected to opposite points of the armature as in Fig. 10. The A.C. magnetising current of the choke is supplied from the dynamo armature. Any out of balance current is permitted to pass through the choke to the half voltage point of the dynamo armature via the slip-rings, with a voltage drop of about 1 per cent. for 25 per cent. out of balance current. Under balanced loading the static balancer passes a small magnetising current only.

Where a heavy out of balance has to be dealt with, two or more choking coils with four or more slip-rings connected to equidistant points of the armature may be used to avoid local overheating of the armature windings.

Dynamo and Battery Plant for Intermittent Supply.

The simplest type of dynamo and battery plant is
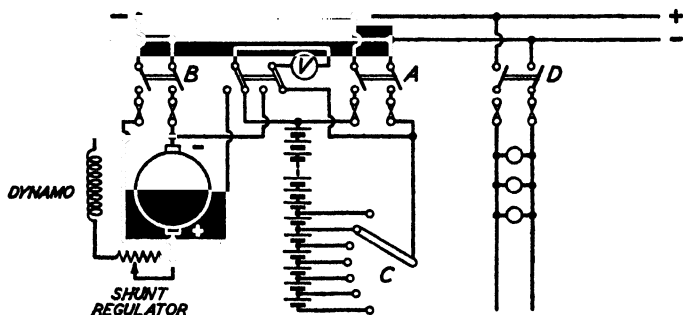
FIG. 11.—SIMPLE DYNAMO AND BATTERY INSTALLATION.

one in which either the generator or the battery may supply the load, but not both together. Fig. 11 indicates the connections.

When the load is taken from the dynamo alone the switch *A* is kept open, switch *B* being closed when the engine is up to speed and the generator voltage correct as indicated by the voltmeter switched on to the
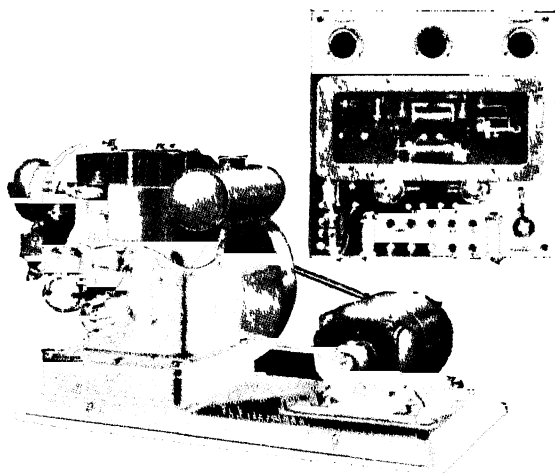
FIG 12—FULLY AUTOMATIC 1 kW SET WITH PETROL ENGINE
(*Petters, Ltd*)

dynamo. The generator voltage is adjusted according to the load, by means of the shunt regulator.

When the engine is stopped the load can be supplied from the battery by adjusting the end cell switch *C* to connect sufficient cells in circuit to make up the normal voltage as indicated by the voltmeter switched on to the battery, then closing the switch *A*, keeping the dynamo switch open. Should the voltage fall due to

increased load or due to discharge of the battery, more cells are connected in circuit by the switch *C*.

When it is necessary to charge the battery the load circuit switch *D* is opened, the engine and dynamo run up to speed and the shunt regulator adjusted until the dynamo voltage is slightly higher than that of the battery. The switches *A* and *B* are then closed, and as the voltage of the cells rises during charging, the shunt regulator is altered to raise the dynamo voltage and maintain the correct charging current. The end cells will probably be fully charged before the rest of the battery, and can then be cut out by the switch *C*. When shutting down the engine the charging current is first reduced to zero by means of the shunt regulator before opening switch *B*. This avoids damage to the switch by arcing and rise of engine speed when switch *B* is opened.

This type of plant would be suitable for a private house lighting installation where the battery could be charged during the daytime.

Dynamo and Battery Plant for Continuous Supply.

This type of plant utilises two end cell regulating switches, one for charging and the other for discharging, the connections being indicated in Fig. 13.

Whilst the set is supplying the load the battery can be put on charge by connecting up all the end cells at switch *C*, running up the generator and adjusting its voltage slightly greater than that of the battery, then closing switch *A*. The shunt regulator is used to adjust the charging current to the required value, whilst the busbar voltage is maintained at the correct amount by the discharge battery switch *B*. The end
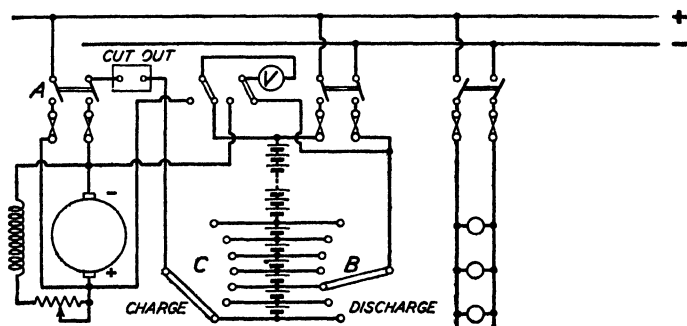
FIG. 13.—CONTINUOUS SUPPLY DYNAMO AND BATTERY PLANT.

cells connected between the charge and discharge switches receive the charging current plus load current and will normally be fully charged before the rest of the battery, when they must be cut out by switch *C*. Switch *B* is used to maintain correct load voltage.

When the battery is fully charged the charging current is reduced to zero, by operating the shunt regulator to bring the dynamo to busbar voltage, before opening switch *A* and stopping the engine. Both charge and discharge switches should then be on the lower voltage studs.

Battery-charging Plant with Starting Switch.

Another arrangement is to use the dynamo to start up the engine; in this case the dynamo has an extra series winding connected in circuit during starting, when the machine runs as a motor from the battery.

Fig. 14 shows the connections for a plant with a drum controller, and it will be seen that the shunt and series windings provide a strong field to give a good starting torque as a motor without a heavy current
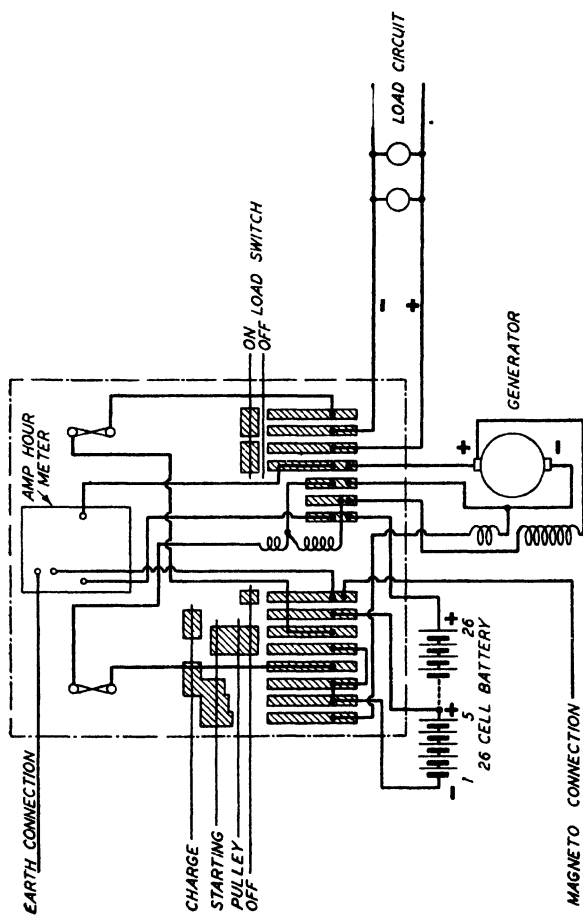
Fig 14.—Charging Plant with Electrical Starter.

being taken from the battery, the series winding being cut out of circuit during charging. The controller is also arranged so that the engine can drive plant directly by means of its pulley when it is not required for charging.

A cut-out is usually fitted on a battery-charging plant to avoid the risk of the dynamo accidentally being run as a motor from the battery should the engine speed fall. This has two coils; the charging current passes through the series coil and tends to hold the cut-out closed and opposes the action of the other coil, which is shunt connected and passes a practically constant current, the latter coil tending to open the cut-out. Should the series coil current fall below about 3 amps. the shunt coil will be strong enough to trip the cut-out and prevent the passage of current from the battery to the dynamo. If the cut-out is not correctly adjusted it may fail to open on zero charging current and the reverse current passing through the series winding may then cause the cut-out to be held closed. In these circumstances the reversal of the armature current of the dynamo may destroy the residual field magnetism and cause considerable trouble.

On the plant indicated in Fig. 14, tripping of the cut-out causes the starting switch to be brought back to the "Off" position and earths the magneto to stop the engine. A float switch operating on the level of oil in the engine sump causes earthing of the magneto if the level should fall too low; the stopping of the engine then allows the cut-out to be released and the controller returns to the "Off" position.

Automatic Plant for Direct Lighting.

This type of plant is suitable for supplying a small installation where the load is generally a good proportion of the total capacity of the plant, but is uneconomical for an installation which has to work on light load for long periods. The dynamo is usually driven by a petrol engine and a low voltage battery is provided purely for operating the control gear and starting up the set. The connections for a typical installation are shown in Fig. 15.

When a load switch is closed current can pass from the low voltage battery through the load circuit and coils *A* and *B*. Coil *B* raises an armature which opens the contacts *M* connecting the magneto to earth and closes the contacts *N* so that coil *D* is energised from the battery. The contacts *O* are then closed to connect the battery to the dynamo so that the latter can run up as a cumulative compound motor to bring the engine up to speed. At the same time the closing of contacts *E* allows battery current to pass through a coil *F* which operates a valve on the induction pipe of the engine to give a rich starting mixture. Just before the engine reaches full speed the governor opens a switch *G* which de-energises the coil *D*, breaking the circuit between battery and dynamo and releasing the choking valve so that the normal running mixture is supplied to the engine.

In the event of the engine failing to start in a given period, due to lack of fuel or other cause, a time switch opens the contacts *H* and shuts down the set to protect the battery from complete discharge. Assuming the engine fires and starts up normally, the building up of the generator voltage causes the coil *J* to close the

Fig. 15.—Automatic Direct Lighting Plant.
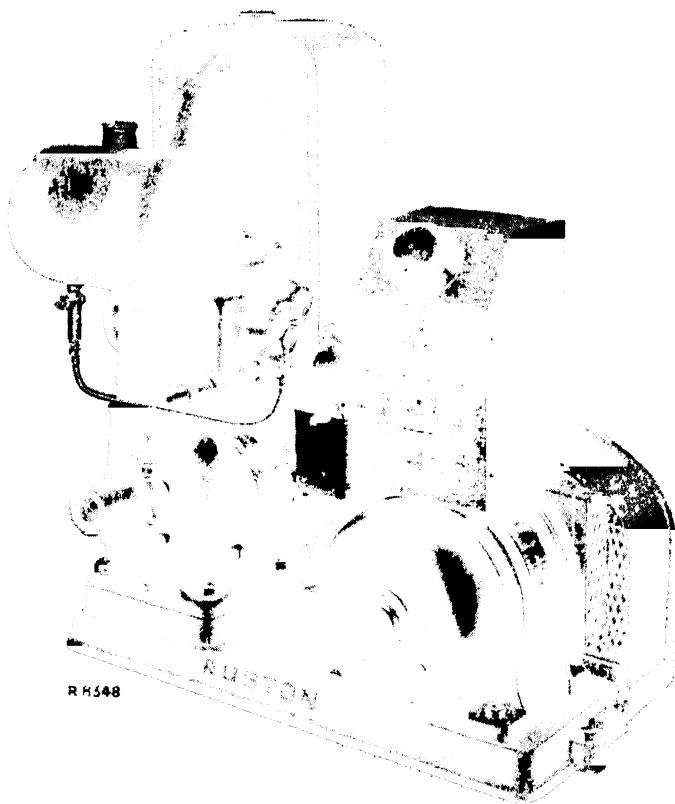
FIG 16 —SELF-CONTAINED ¾ kW PETROL-ENGINED LIGHTING SET

(Ruston & Hornsby, Ltd)

switch K so that the dynamo supplies the load direct as a compound machine, and also passes a small charging current to the battery through the resistance L. When the load is switched off the coil B is

de-energised and the contacts M earth the magneto to stop the engine; the coil *J* is then de-energised and the switch *K* opened.

Automatic Lighting Plant with Battery.

The type of plant next to be described is more economical than the previous type when a small current may be required for fairly long periods. In this case the engine may be driven by petrol or crude
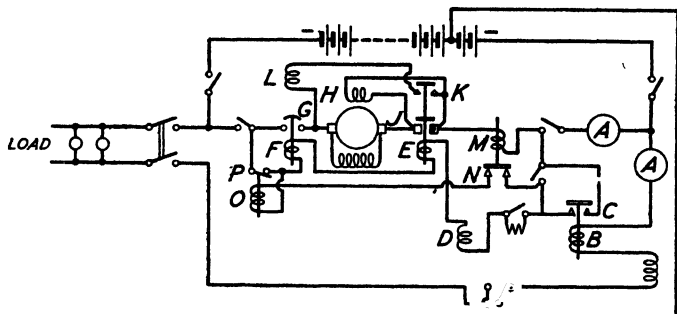
FIG 17—AUTOMATIC DIESEL BATTERY PLANT.

oil. The connections for a typical diesel plant are shown in Fig. 17.

Switching on of the external load allows current to be drawn from the battery at normal voltage. Should the current exceed about 20 per cent. of full load the coil *B* will close contacts *C* and allow current to pass through the coils *D, E* and *F*. Coil *F* closes the main switch *G* and connects the dynamo across the battery with current passing through the series starting winding *H*, and the dynamo then starts to run as a motor. A wedge is arranged under the spindle of the exhaust valve so that the valve is held partly open to relieve
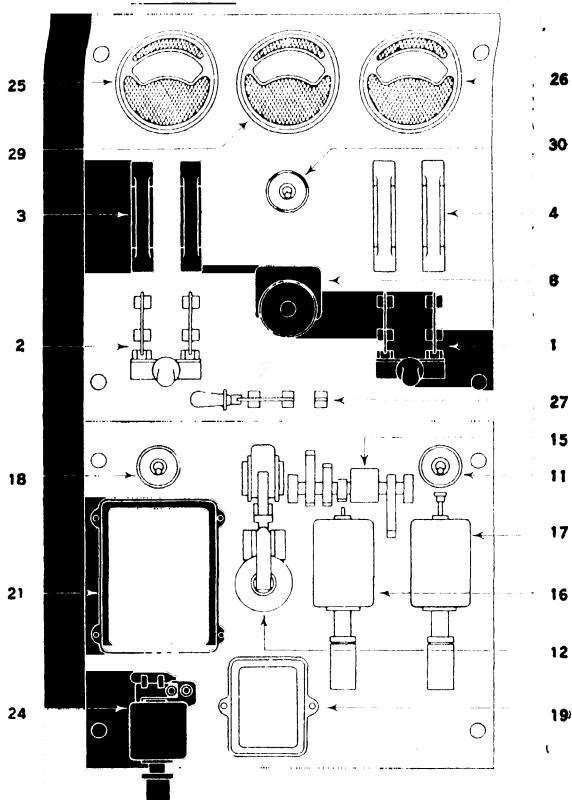
FIG. 18. - SWITCHBOARD FOR AUTOMATIC DIESEL-GENERATING SET WITH FLOATING BATTERY.

The various components are: (1) Battery Switch for isolating the battery; (2) Generator Isolator Switch; (3) Generator Fuses; (4) Load Fuses; (8) Shunt Regulator; (11) Emergency Switch; (12) Starting Contactor; (15) Short-circuiting Switch; (16) Short-circuiting Coil; (17) Circuit-breaker Coil; (18) Special running Switch; (19) Polarised-relay for disconnecting engine from battery should engine fail; (21) Load-relay for starting and stopping plant; (24) Delay start Switch; (25, 26) Generator and Discharge Ammeters; (27) Special Charge Change-over Switch; (29, 30) Voltmeter and Switch.

The back of the board wiring diagram is given in Fig. 19.

the load and allow the engine to reach full speed rapidly.

Coil *E* has a time lag and after about half a minute it closes the contacts *J* to short circuit the series field windings; at the same time coil *D* draws the wedge from the exhaust valve and full compression is obtained, a device also being operated to allow injection of the fuel oil. Contacts *K* close with *J* and coil *L* is energised to control a change-over valve so that the compression during acceleration is about 600 lb. per sq. in., whilst the running compression is about 450 lb. per sq. in.

Coil *M* forms part of a reverse current relay operating contacts *N*, so that current is passed through coil *O* as long as current passes from the battery to the dynamo. Should the engine fail to start in about one minute the time lag of *O* allows the contacts *P* to open to de-energise the coils *D*, *E* and *F*; the opening of the main switch *G* then shuts down the set to protect the battery. With a normal start, the engine picks up speed and takes control, the dynamo voltage rises above that of the battery so that a reverse current is passed through *M*, and the "stopping" coil *O* is rendered inoperative. The dynamo then supplies the load and passes a small charging current through the battery.

The engine is fitted with an electrically controlled governor, so that its speed is increased with the load to maintain the dynamo voltage slightly higher than that of the battery. If the load falls below 20 per cent. of full load current, the coil *B* releases the contacts *C* and shuts down the engine. Should the engine speed fall due to lack of fuel or other cause the reversal of current through coil *M* allows the coil *O* to be energised and the set is shut down in about one minute.

Should a small current be taken over a long period of time the battery may become discharged without the set being started up, and it may then be necessary to run the plant with the automatic features cut out whilst the battery is recharged.
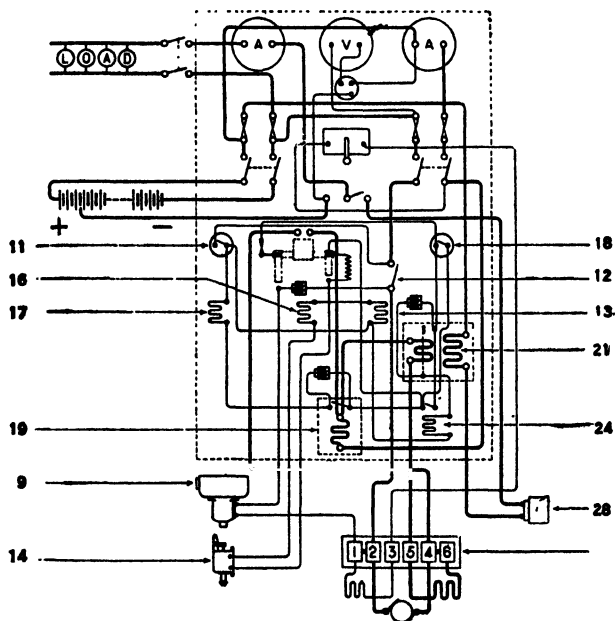
FIG. 19.—WIRING DIAGRAM OF SWITCHBOARD SHOWN IN FIG. 18, SHOWING ALSO CONNECTIONS TO GENERATOR AND AUTOMATIC EQUIPMENT ON DIESEL ENGINE.

Numbering of components as in Fig. 18 with following additions: (9) Starting Valve Solenoid on engine; (13) Starting Contactor Coil; (14) Stopping Solenoid or Fuel Cut-off Solenoid on engine; (28) Magnetic Governor on engine for ensuring constant voltage. The various automatic components fitted on the engine are shown in Fig. 21.

A complete circuit of plant is shown in Fig. 20.

Fully Automatic Plant with Large Storage Battery.

With this type of plant the load is usually supplied from the battery, *the dynamo being reserved for charging the battery or assisting during periods of very* heavy load. The plant described gives very good voltage regulation and has the advantage that the
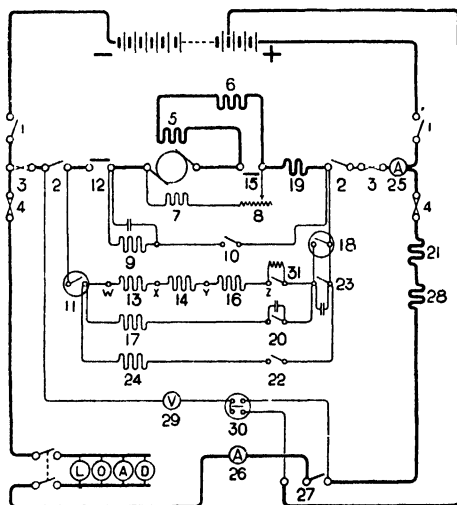
FIG. 20.—COMPLETE CIRCUIT DIAGRAM OF AUTOMATIC DIESEL GENERATING SET WITH FLOATING BATTERY. See also Figs. 18, 19 and 21.

battery cannot be run down due to long periods of light load, also the dynamo always works on full load.

The set is controlled by variation of battery voltage causing the voltmeter to operate contacts as the voltage rises or falls. In the smaller plants the battery supplies the load until the voltage falls to a predetermined value, when closing of the lower voltage contacts
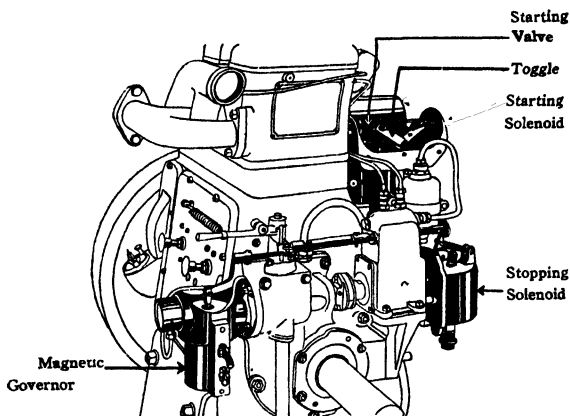
FIG 21.—AUTOMATIC EQUIPMENT ON DIESEL ENGINE OF 10 kW PLANT

(*Lister*)

energises a relay which closes the main contactor between the battery and dynamo. The dynamo then runs as a motor to speed up the engine. The dynamo has three sets of brushes and, when the dynamo is generating, rise of voltage is prevented by an auto-switch which connects the load circuit on to the third set of brushes. When the battery is fully charged the rise of voltage causes the high voltage contacts of the voltmeter to close and trip out the set, after which the battery continues to supply the load.

Better voltage regulation is obtained on the larger, higher voltage, plants by means of a cell-regulating battery switch operated by a small pilot motor. Fig. 22 shows the arrangement for a 100-volt circuit. Assuming the load is being supplied by the battery at 102 volts; as the battery discharges, or should the voltage drop of the battery increase due to increased

Fig. 22.—Automatic Plant with End Cell Regulations.

load, the voltmeter will close the low voltage contacts when the voltage falls to 100 volts. A relay will be energised and cause the pilot motor to bring another cell into circuit to raise the voltage. Further fall of

voltage later may cause the pilot motor to connect other cells in circuit until eventually all the battery is in use. Should the voltage continue to fall the operation of the discharge pilot motor then energises a relay which connects the dynamo to the battery and allows it to run the engine up to speed, when charging is started.

The battery voltage rises and at 103 volts closing of the high voltage contacts causes the discharge pilot motor to cut out one cell and so on to maintain the supply voltage between 100 and 103 volts. Similarly an automatic relay cuts out the end cells on the charging side when these are fully charged. When the discharge switch has cut out all the end cells from the load circuit and the voltage of the rest of the battery has risen to 103 volts the discharge pilot motor energises a trip coil to open the main contactor and shut off the fuel to stop the engine.

When the load required over long periods may vary between wide limits the automatic plants operated by the load current may be working for long spells under uneconomical light load conditions, whilst the disadvantage of plants using a large battery to supply the load lies in the low efficiency of battery working.

These disadvantages can be avoided by having an automatic plant with two or more separate engine and dynamo sets of different sizes. The smallest set would start up first, and should the load rise too high one of the larger sets would then start up and the small set shut down. Further increase of load then causes the smaller plant to start up again and run in parallel with the second plant, or a third large plant might be brought into operation.

CHAPTER II

EMERGENCY STAND-BY SUPPLY SYSTEMS FOR HOSPITALS, PUBLIC BUILDINGS, ETC.

Emergency Lighting.

A FEW years ago, when the National Electricity Grid was initiated, few people would have forecast that, side by side with this development and interconnection of our electricity resources, there would be a growing interest in the subject of emergency lighting. That, however, is just what has happened, and during the last ten years or so, but increasingly during the last four or five years, great attention has been given to methods by which total darkness in important situations can be prevented. Such darkness obviously will result if there is only one source of light and this fails.

The Law on Emergency Lighting.

Only a comparatively small proportion of the emergency lighting systems now in use have been installed under compulsion from the law. The others are due to the growing sense of responsibility of the owners, architects, and engineers of buildings in which people congregate, often in very large numbers. So far as the law is concerned, mainly cinemas are affected, since their equipment has to comply with the Cinematograph Regulations, 1923, which are enforced under the Cinematograph Act, 1909. Theatres, although not included in this Act, are usually treated

in a similar manner under the power of bylaws issued by various county and borough councils. There are many situations, however, where there is no compulsion to provide emergency lighting. For instance, civic and other public buildings, stores, hospitals, asylums, schools, railway stations, aerodromes, restaurants, hotels, blocks of flats, important offices, banks, factories, ships, and many other locations are examples of the type of building or situation in which it is becoming an increasingly common practice to provide some alternative means of lighting.

Effect of the Grid.

Although in many districts the interconnections provided by the Grid between adjoining districts have resulted in making the available electricity supply more reliable, there are cases where this unification of supply has had different results. For instance, in London a few years ago many of the important streets had supplies from two entirely different generating stations which had no interconnection. The Grid system swept this away, and to-day only the Charing Cross and the St. James and Pall Mall Supply Companies are recognised as providing separately generated and transmitted supplies, suitable in a limited area of London for emergency lighting services, where the main lighting is supplied from some other network. The London County Council consulted the Electricity Commissioners on the subject, and the latter, as a result of the withdrawal of some of the former separate services, recommended storage batteries as the best means of providing emergency lighting in places of entertainment.

Fig 1.—General View of Stand by Diesel Engine Plant with New Engine in Foreground and with 66 kV Switch-board Gallery on the Right

GENERAL CONSIDERATIONS REGARDING EMERGENCY LIGHTING SCHEME

When an emergency lighting scheme is under consideration, there are several factors which affect the choice of the particular system to be used and the extent of such lighting. There are such factors to be considered as:

(1) The class of building;

(2) Whether or not the law applies;

(3) The ease of installation (affected by the question whether the emergency system is an addition to an existing installation or part of a completely new installation, where it is much easier to include a comprehensive emergency system);

(4) The cost.

Cinemas.

For instance, a cinema is required to have emergency lighting in all parts by law. Cinema installations are dealt with in more detail in the next chapter.

Hospitals.

A hospital is not compelled to have any, and shortage of funds sometimes restricts the use of emergency lighting to the most important spot, the operating theatre.

Flats and Stores.

Again, in a large block of flats it may only be necessary to have a few emergency points for the corridors and staircases; in a large store, evenly distributed emergency lighting is desirable, and so on.

In New and Old Buildings.

Where the installation is a new one, particularly in a new building, there is no difficulty in including the wiring for a comprehensive emergency system, even if the emergency plant is not purchased immediately. Such an arrangement of wiring need add very little to the initial cost of essential wiring, and is well worth doing with all new buildings of an important character. This wiring would serve part of the normal lighting of the building, and would be usefully employed even if the stand-by battery is in the end not added. When it is desired to add emergency lighting in a building where the ordinary installation is already complete, the additional wiring generally has to be arranged without running surface wiring on the one hand, or damaging the structure or decorations on the other. This rather tends to limit such additions to those places where they are essential to the exclusion of those where they are desirable but less important.

STORAGE BATTERY EMERGENCY SYSTEMS

It will be of assistance if some of the main features of emergency systems are tabled, to be described in greater detail under the various applications.

Types of Batteries.

For storage battery installations on shore, batteries are almost invariably of the "Planté" type, with heavy positive plates formed from pure lead in finely "lammelled" castings, and box-type negative plates. In most cases glass boxes are used, but
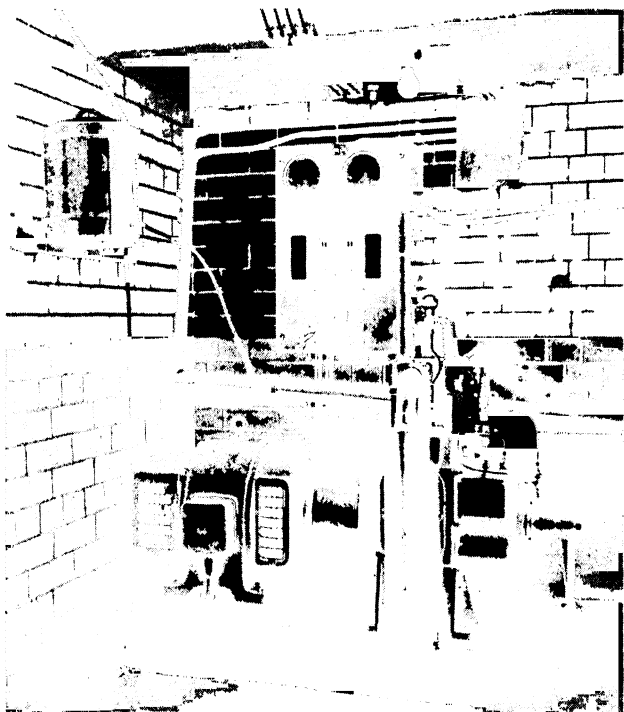
FIG 2 A 5 kW D C GENERATOR DIRECT COUPLED TO A CROSSLEY B V D I VERTICAL SINGLE CYLINDER FOUR STROKE DIESEL ENGINE DEVELOPING 10 H P AT 1 500 R P M AND INCORPORATING A RICARDO DESIGN CYLINDER HEAD

This set has recently been installed in the A R P shelters of a large tobacco factory to provide a stand by source of electric current in the event of interruption of the normal supply

(Crompton Parkinson Ltd)

batteries of the larger type, above 900 ampère-hours, usually have lead-lined wood boxes For use on ships or vehicles, such as trains, a different form of cell is employed, better calculated to withstand the vibration.

This type has pasted plates with special separation to ensure the retention of the paste in contact with the grids. Such cells are usually assembled in ebonite boxes with lids, and trays accommodating several cells each are provided for the convenient stowing of the battery in its compartment.

Automatic-switch Circuits.

Some systems employ automatic change-over switches, and they are used in several ways. In the purely emergency system the automatic switch changes the battery over from charging to discharging, should the mains fail. The emergency lights are used only in the event of a failure of normal supply, and come on automatically at such a time. There is no fixed relationship between the mains voltage and the battery voltage, which may be decided at any convenient figure.

In the "continuous" system, the automatic switch changes the lights over from their normal source of supply to a battery or direct generator plant at approximately the same voltage, when the former fails.

Where the supply is A.C. it is not essential for the battery to be of the same voltage as the mains, since a step-down transformer forms an easy method of providing an A.C. supply at the same nominal voltage of any selected battery. If the main supply is D.C., it is advisable to use a battery of the same nominal voltage as the mains.

For use with shadowless lamps in the operating theatres of hospitals, a special series-wound automatic switch is used to give local control.

Automatic-switch circuits may be duplicated or
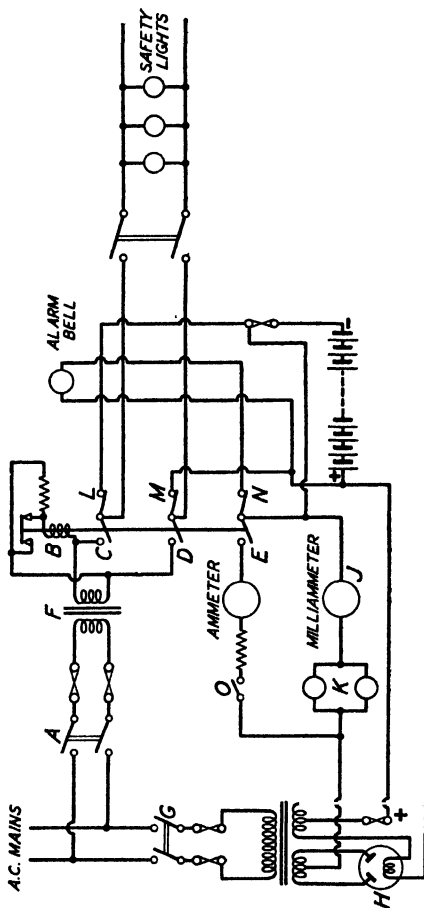
FIG. 3.—TRICKLE CHARGE STAND-BY PLANT.

Should the main supply fail the coil *B* is de-energised and contacts *C*, *D* and *E* are opened whilst *L* and *M* are closed to connect the emergency lights across the battery. Contact *N* closes at the same time and rings an alarm bell. When the main supply is resumed coil *B* allows the emergency lights to be fed from the mains again and trickle charging is resumed. If the failure has been of many seconds duration the battery can be given an increased charge through the contact *E* by closing the switch *O*. Such a set can be used with a D.C. main supply, in which case the transformer and rectifier are not required. *K*, lamps for trickle charge.

triplicated where desired, and sometimes it is convenient to use a 3-phase, 4-wire circuit with a special form of automatic switch. An important feature of the automatic-switch system is the "trickle charge" of the battery, which the system makes easy.

"Keepalite" Trickle Charging System.

One of the best-known emergency lighting systems is the "Keepalite" System (Brit. Patent 313248). In this a storage battery for emergency purposes is controlled by an automatic switch, and means are provided for giving a high rate of charge and an alternative trickle charge. The purpose of the latter is to ensure that the battery will remain in a fully charged and healthy condition ready for an emergency discharge. Large numbers of batteries employed in this way for the past eight to ten years have invariably given excellent results, and still show no sign of wearing out. The trickle charge is given continuously and is practically never in excess of 1 milliamp. for each ampère-hour of the capacity of the battery. For instance, for a 50-A.H. battery at the 10-hour rating the trickle charge would not exceed 50 milliamps. For larger batteries the proportion is usually less.

After any emergency discharge, the higher rate of charge must be switched on and the battery brought up to a state of full charge before being left on trickle charge again. This higher rate of charge is usually switched on by hand, but where required may be entirely automatic through the use of suitable relays. A wide variety of circuits is available to suit differing circumstances.

Floating Systems.

The floating system is frequently used in cinemas, owing to the present regulations affecting such buildings in England and Wales. The argument for it is that the battery, at all material times, is connected direct to the safety lights, even though these normally derive their supply indirectly from the mains through a converting device. In practice, the battery is less easily kept in a constant fully charged condition than with a system employing trickle charge. A compensated choke control for rectifiers used with batteries on the floating principle has recently been introduced, and gives much steadier results than the ordinary floating system with a rectifier (see next chapter).

Motor-generators are sometimes employed with batteries in floating systems, but rectifiers are more commonly used to-day.

Rectifiers.

Rectifiers of various types can be employed, and the most suitable in any given case depends on initial cost, renewals cost, efficiency, space required, dependability, ease of control, etc.

For moderate loads the hot-cathode valve rectifier is attractive, being compact, reasonable in cost, and not requiring frequent renewals. The valves are usually guaranteed for two years, but under many conditions of service last considerably longer. The hot filament eventually ceases emission, thus ending the useful life of the valve.

For heavier loads the mercury-arc rectifier has claims, particularly at the higher voltages. Although bulb renewals are expensive, there is no part of the

bulb which is inherently consumable, and under all reasonable conditions a long life can be expected from it. The copper-oxide rectifier is excellent for any reasonable load, but is rather high in first cost except in the case of low currents at moderately high battery voltages, where it is undoubtedly the best type to employ. The life is said to be indefinitely long, since there are no consumable parts.

Motor-generators.

These are still employed sometimes in place of
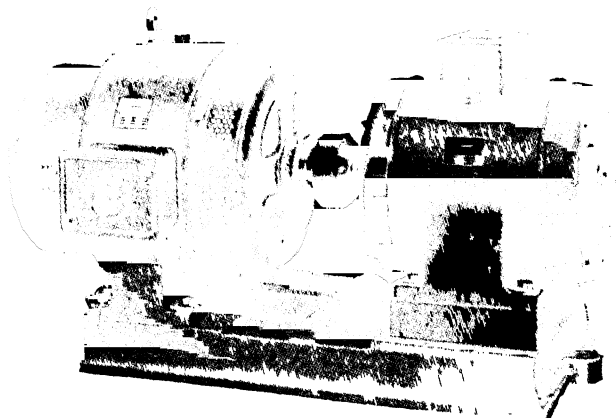
FIG. 4.—A MOTOR GENERATOR, WITH GENERATOR DRIVEN BY AN A.C. SQUIRREL-CAGE MOTOR
(Mather & Co., Ltd.)

rectifiers in battery systems. Where there is an A.C. supply a fairly steady output can be obtained, and the generator may be compound wound for floating systems, or shunt wound if used solely for charging the battery in automatic-switch systems. A 3-phase motor is usually employed, with a star/delta, auto-

transformer, or slip-ring starter as required by the size of machine and by the supply authority's regulations. The shunt regulator must give a sufficiently wide range of control of the generator voltage to cover the range of voltage of the battery on charge, and for floating systems fine steps of regulation are required about the floating voltage.

Combined Engine-Generator-Battery Stand-by.

About three hours is the usual emergency period for which batteries are installed. There are cases, however, where it is desired to be able to maintain some supply perhaps for several days in the event of the interruption of the normal supply for such a period. Such cases are not as a rule based on an ordinary conception of a supply breakdown, but have in view the protection of
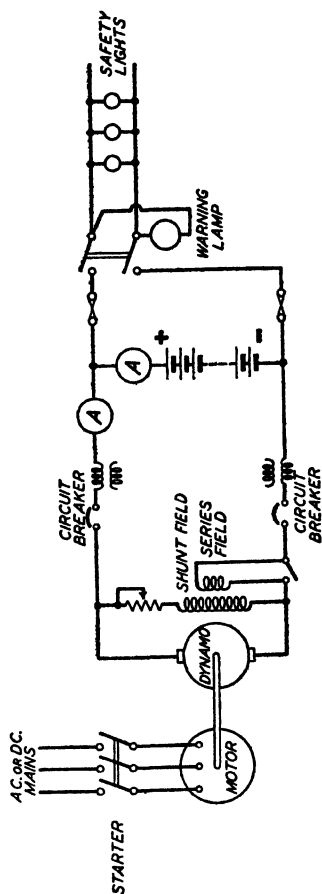
Fig. 5.—Floating Battery Generator Plant.

some vital building or industrial process in the event of damage to the street mains by air attack.

In this case an engine driven generator would be employed as the means of giving some supply indefinitely. In connection with this an automatically controlled storage battery may be used to give an instant supply on the failure of the mains, the engine set being then started up to take over the load, but with the battery floating or standing-by in case of any temporary difficulty with the engine. The systems in use would in general be one or other of those described in Chapter I.

ENGINE-GENERATOR STAND-BY

An alternative method of meeting the emergency conditions described above is the use of an engine-generator set which automatically starts up immediately the mains supply fails.

A detailed description of the design and operation of plant of this nature is given below.

It includes a system of control by which the plant automatically self-starts, upon failure of the normal supply, continuing to run so long as the emergency persists, and automatically stopping itself when normal conditions are restored.

In most cases the equipment includes an automatic transfer panel which, on a mains failure, will substitute the emergency supply for the mains, feeding the normal circuits, and thus obviating the need for wiring special emergency lighting points.

Automatic emergency plant of the type described is standardised in a range of types, and in individual sizes up to 40 kW.

For the simplest applications, where lighting only is the main requirement, a 230-volt D.C. type of automatic plant is usually entirely satisfactory. On the other hand, where complete provision of lighting and power is required, the emergency plant can be arranged to duplicate exactly the normal mains service.

Automatic A.C. Emergency Plants.

The control gear used is arranged in a double cabinet. The "power" section on the right of the control panel dealing with the power output, receives current from the alternator through a 3-pole and neutral switch fuse mounted on the lower portion. From the live side of this switch small connections are also taken to the left hand "control" section, so that the voltage regulating apparatus and voltmeter (fed through its own fuses within the swing doors) are in circuit before the mains ironclad switch is closed.

Automatic Change-over Switch.

Above the ironclad switch, in the right hand cabinet, the automatic change-over gear is housed and accessible by removing the large inspection cover. This automatic change-over switch consists of two 4-pole contactors of the latched-in type, the lower set for connecting the plant to the load and the upper set for connecting the mains to the load.

Load Ammeters and Control Fuses.

The three ammeters show the phase currents passing to the load circuits, whether fed from the mains or from the plant. The mains connection is taken to
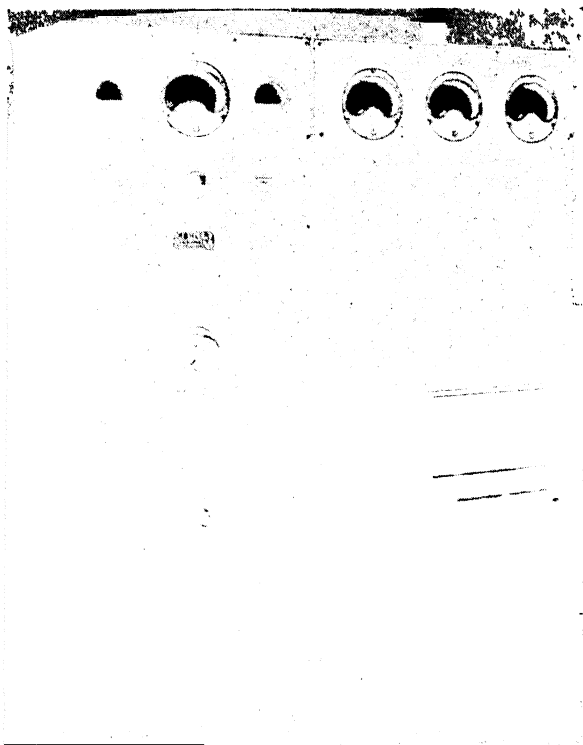
Fig. 6.—Automatic Control Panel for 30 kW Kohler-Perkins Automatic Stand-by Plant Incorporating Change-over Gear

the upper part of the change-over switch, through the top or side of the cabinet.

In the left hand section, the lower portion within the swing doors contains the automatic starting and stopping relays and also a row of 5 amp. control fuses.

Voltage Regulator.

On the plant itself an Isenthal belt-driven automatic

voltage regulator is mounted, whilst the rectifier, transformer and exciter-field-resistance, associated with this regulator, are mounted in the upper part of the left hand section of the cabinet.

For normal use with automatic voltage regulation the switch-key on the regulator itself should be turned to the left or right, and changed from one position to the other once a month, or at regular intervals. If hand control of the voltage is desired the Isenthal regulator on the plant must be set with its switch-key in the vertical position, and under those conditions the hand wheel voltage regulator on the panel is usable.

Battery Charging.

Trickle charging for the starting battery is provided from a transformer, metal rectifier and resistance in the left hand section. The small switch marked "Trickle Charger" controls the A.C. feed to this gear which is supplied from the load-output side of the automatic change-over switch. As a result, the trickle charge is available whether current is supplied from the mains or from the plant. This trickle charger switch should be always on. Two rates of charge, "Trickle" and "1 ampère," are provided by the other switch.

The "Trickle" rate, approximately 40 milliamps, is shown on the left hand small meter. This should be left flowing continuously, day and night, to compensate for the natural leakage which takes place in the battery.

Hydrometer readings should be taken from time to time to ensure that this compensation is adequate, but should the gravity show signs of falling, the higher rate should be used to correct matters. This merely

requires the charge rate *control switch to be turned down into the* 1 *ampère position, when the* 1 *ampère* charge will be shown on the small meter above the switch.

Once the gravity is up to normal the trickle rate should be restored.

Automatic Control Switches.

In the centre of the left hand control cabinet the "Mains Control" and "Auto-Stop" switches will be seen on the left. Both of these should be normally on (down).

The object of the "Mains Control" switch is to create the effect of a mains failure when it is desired to test the automatic starting of the plant. If this switch is turned up, automatic starting will take place and the machine should continue to run until the "Mains Control" switch is restored to the "on" position, when it will stop automatically provided the "Auto-Stop" switch also is on.

The "Auto-Stop" switch, if turned off (up), enables the plant to keep running, after restoration of a mains failure, in case there are some circuits which have been switched over to the plant by hand, and it is desired that the plant should *not stop* until these have been switched back to receive current from the restored mains.

Push Button and Hand Start.

In addition to the automatic starting due to a mains failure, the plant may be started at any time by using the *push button* mounted below the main voltmeter. This operates on the same lines as a vehicle electric
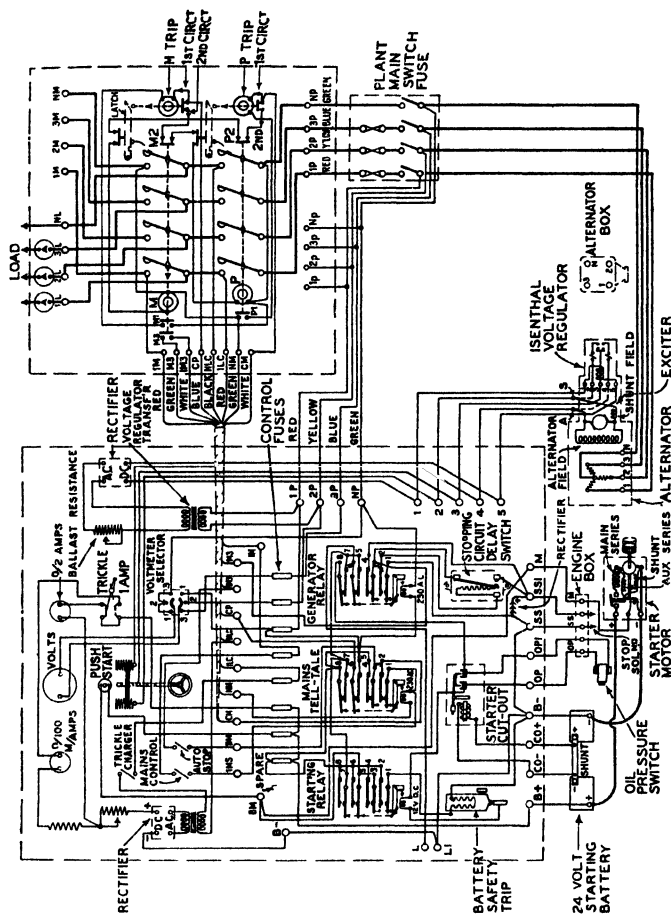
FIG 7 WIRING DIAGRAM OF CONTROL AND POWER PANELS FOR KOHLER-PERKINS AUTOMATIC EMERGENCY PLANT.

starter and should therefore be depressed only when the machine is stationary and should be released as soon as the engine commences to fire regularly.

Starting of the engine can also be carried out by hand, for which purpose the decompressor lever on the end of the valve cover should be lifted, and dropped down after the engine has been revolved a few times by hand, after which with the help of the flywheel momentum it will be found to start readily.

The machine can also be stopped by hand at any time by moving the fuel control rod into the shut position, but it should be remembered that it is liable to self-start again immediately, should there be no A.C. mains "holding off" the starting mechanism.

Battery Safety Trip.

In connection with the self-starting control which is inside the swing doors, a thermal trip switch will be found to the left of the cut-out with the glazed cover.

This thermal trip is for the purpose of interrupting the starting circuit should the engine fail to start after about ½ minute's cranking, such as through lack of fuel. This is to save the starting battery from exhaustion.

Automatic Starting Trigger.

This thermal trip switch may also be operated by hand, under which conditions it can be used as a trigger to set the control gear ready to respond to a mains failure.

This trip merely affects the automatic starting circuits, and does not prevent the hand use of push-button starting.

Testing.

The automatic starting and change-over gear should be tested every two weeks by turning off (up) the "Mains Control" switch. The plant should be allowed to run for at least twenty minutes on each occasion to get thoroughly warm.

Operation of Kohler Automatic Control.

This system is applied to Kohler A.C. emergency plants in which the self-starting is effected by means of a separate starting motor which includes a self-contained solenoid switch. This solenoid switch is energised by the communication of 24-volt positive current to the control terminal "M" on the motor itself.

Fig. 7 shows the complete wiring, from which it may be seen that on energising contact "M" on the starting motor, the armature slides forward to engage with the gearwheel, smooth engagement being effected by the slight rotary motion given at the same time. When fully engaged, a latch in the motor itself is released, which allows full power to be applied to the motor for the starting effort. As soon as the connection to terminal "M" is interrupted, the internal switch opens, the motor is drawn back out of engagement, and stops.

APPLICATION OF EMERGENCY LIGHTING TO HOSPITALS

Storage Battery Installations.

One of the most obvious uses of emergency lighting is to be found in hospitals, particularly in the operating

theatres, where the sudden failure of light during an operation might have fatal consequences. Hundreds of hospitals are now equipped with emergency lighting batteries, the size of such installations varying from 12 volts 30 A.H. to 230 volts 400 A.H. Many up-to-date hospitals have had included, either during extensive alterations and rewiring, or during building, a comprehensive emergency lighting system to protect the operating theatres and attendant rooms, the main wards, the corridors, and the staircases and fire escapes. In such cases, because of the fairly extensive runs of wiring and because of the storage capacity required, it is advisable to employ a battery of the same nominal voltage as the lighting mains, e.g., 230 volts. The capacity of the battery can then be determined from the total wattage of the points connected to the emergency system and the period for which the battery is to supply these in an emergency. From one to three hours is the usual allowance.

Use of "Continuous" System.

The automatic-switch system is by far the best for such a situation, and as has already been mentioned, there are two principal ways of using this—the "continuous" and the "emergency" types of circuits. The former has the advantage that the lights on the circuit may form part of the ordinary illumination, being supplied normally from the mains, and only from the battery if the mains fail. It is important to make sure beforehand, however, that it can be arranged that those particular lamps are switched on each evening. It will be seen that, since they are in effect part of the general lighting, all of which may not be

required to be in use, it is essential that it is not the lamps on this special circuit which are left "off". A proper routine will ensure this.

Separate Emergency Wiring.

The other method, the "emergency" system, requires entirely separate wiring and lamps, and these are, of course, additional to the wiring and lamps for the normal illumination. This system, therefore, is usually kept to smaller, more localised circuits. It has the advantage, however, that all the lights on it instantly light up when the mains supply to the ordinary lighting is interrupted, and not until then. There is consequently no need for any hand-operated switches between the lights and the automatic change-over contactor.

Mixed-duty Circuits.

It can be arranged where required that part of the load is on the "continuous" and part on the "emergency" system, by the use of a suitable contact arrangement on the automatic contactor. Also it can be arranged, where desired, that the special circuit can be instantly converted from a "continuous" to an "emergency" circuit and vice versa, and this arrangement is useful in some cases. For instance, it would be useful and economical to use the special circuit as part of the ordinary lighting, and yet have the security that it will instantly be connected to the battery if the mains fail. To obtain this double method it is only necessary to have a switch between the A.C. supply and the contactor, keeping the coil of the latter energised from the mains side of that switch. If a step-down transformer is used (as with 100- or 50-volt equipments), the principle still holds good.

Operating Theatres.

It is a common practice to-day to illuminate each operating table by means of a shadowless lamp, optically designed with great care to ensure that for a minimum of energy an illuminating beam is concentrated on the table, of such a type that the head of the surgeon bending over the patient throws no appreciable shadow. The use of a limited capacity of illuminant is desirable, since otherwise there is a troublesome amount of heat thrown on to the neck and head of the surgeon. Hence the lamps used are frequently of high efficiency and have, therefore, a shorter life than an ordinary lamp, and are quite likely to burn out during an operation, since they are not used at other times. Such a filament failure is not covered by the contactor, which operates on interruption of the main supply to which its coil is connected. For the protection of the operating-table lighting, therefore, use is made of a form of local automatic switch, commonly known as a combined switch and relay, or briefly, switch-relay. It is not strictly a relay, but is generally of a size and type associated with relays. The "relay" is a small automatic switch, generally of the mercury pattern, the actuating coil of which is of the series type for connecting in circuit with the main lamp of the shadowless fitting. The coil is designed to operate on very little energy, so that there is no appreciable voltage drop through it. So long as the main lamp is taking its usual current the coil and armature keep open the contact or mercury switch of the "relay". Should a local fuse blow, the main filament burn out, or the mains fail, the "relay" is de-energised and its contact closes, thus connecting the battery to the three
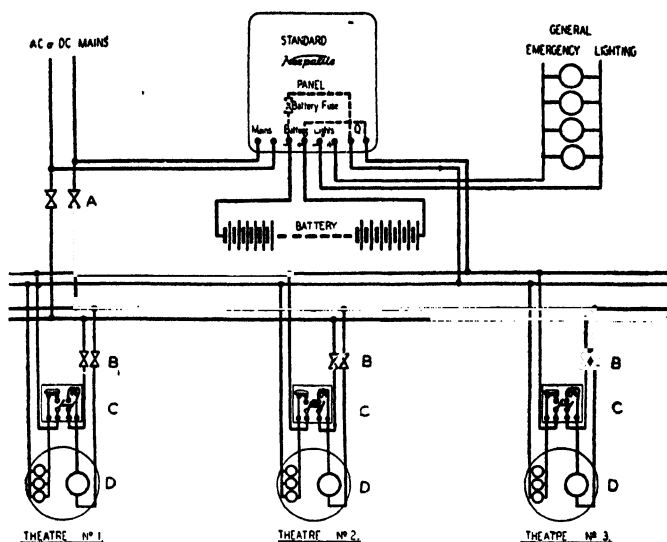
FIG. 8.—DIAGRAM SHOWING "KEEPALITE" CONTROL GEAR, BATTERY, AND SPECIAL SWITCHES FOR THREE OPERATING THEATRES.

A, main distribution fuses; *B*, theatre sub-fuses; *C*, switch relay on theatre walls; *D*, special operating lamps.

or four emergency bulbs, usually situated within the same large reflector as the main lamp.

It will be seen from this action that every time the main lamp is switched off the "relay" would try to light up the emergency bulbs, and it is therefore advisable, and usual, to couple to the single-pole switch controlling the main bulb a second single-pole switch (i.e., two poles of one double-pole switch will do) in series with the emergency circuit, so that when ordinarily switching off the lamp the battery circuit is disconnected at the same time.

Fig. 8 shows a typical diagram for a hospital with
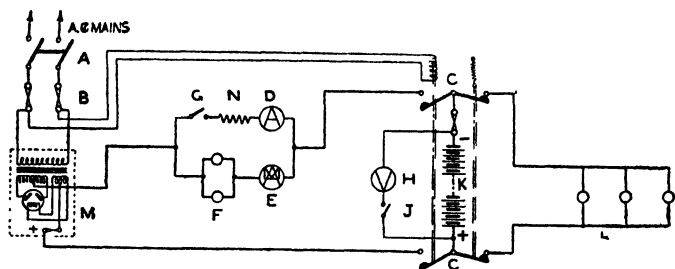
FIG. 9.—DIAGRAM OF CHARGING AND CONTROL GEAR OF TYPICAL "NORMAL-OFF" TYPE "KEEPALITE" AS USED IN HOSPITALS.
A, Main switch. *B*, Main fuses. *C*, Change-over contactor. *D*, Ammeter. *E*, Milliammeter. *F*, Lamps for trickle charge. *G*, Quick-change switch. *H*, Voltmeter. *J*, Voltmeter switch. *K*, Battery. *L*, Emergency lights. *M*, Rectifier. *N*, Quick-charge resistance.

three operating theatres, each with its own switch-relay. There is also a circuit of emergency lighting for wards and corridors controlled by the automatic contactor to operate when the mains are interrupted. Fig. 9 shows the wiring diagram of the control panel itself in greater detail. The secondary lighting in this example is of the purely emergency type.

Several Floors or Different Blocks.

Fairly often a large hospital occupying several floors of a building is wired up so that only one phase of the main 3-phase system supplies the general lighting in any given section or on any floor—say phase *A* for the ground floor, phase *B* for the first floor, and so on. With such an arrangement there is a possibility of the failure of one phase out of the three affecting the lighting on only one floor. If that does not happen to be the phase controlling the emergency lighting contactor it would not operate, and that floor would be

left in darkness. Therefore in such cases there is either a separate contactor for the emergency lighting on each floor or in each section, or an arrangement of relays that brings on all the emergency lighting, no matter which phase fails.

Some hospitals, particularly sanatoria and isolation hospitals, are divided into a number of completely separate blocks, perhaps separated by 20–50 yards from each other. To give the best emergency lighting safeguard in such cases it is advisable to have a separate small battery with its automatic emergency lighting control for each block.

Avoiding Unnecessary Operation of Emergency Batteries.

Sometimes objection is raised to the possibility of the mains failing during daylight hours, and so, causing the automatic switches to connect the emergency lights to the battery unnecessarily. Of course, it is possible to use a hand switch and disconnect the emergency lamps during daylight hours, but there is always a danger that this switch may be left off afterwards and thus be off when a real emergency arises. Such hand switches, therefore, should only be used with purely emergency systems if they are linked with the switches controlling the ordinary lighting. Thus in many county council and other hospitals the switches controlling the ordinary lighting at important points (e.g. around the operating theatres) are double-pole, the second pole connecting to the emergency lighting points. The latter, however, only light up if the mains fail during the time that these switches remain "on". Fig. 10 will make this point clear.
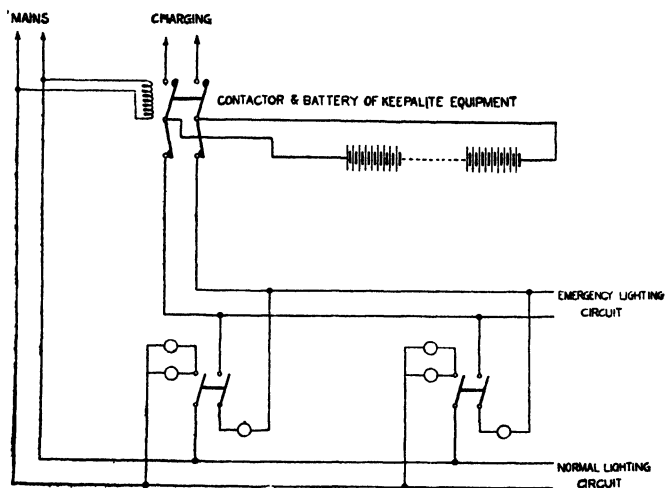
FIG. 10.—DIAGRAM TO SHOW LINKING OF SINGLE-POLE SWITCHES FOR "NORMAL-ON" EMERGENCY LIGHTING POINTS.

Another method is to incorporate an electrically wound time switch, which is set to disconnect the emergency lighting system during daylight hours, so that an interruption of the main supply, causing the contactor to change over, will not wastefully discharge the battery.

Diesel-Electric Emergency Supply for Hospitals.

Diesel-electric sets possessing a number of special features have been installed in hospitals to provide electricity supply in the event of an emergency. Technical details of such an installation are given below.

In Fig. 11 is shown the general layout of the two diesel plants in the hospital itself. These have a capacity of 37½ kV.A., at 400 volts, 3-phase, 50 cycles. The plants embody Perkins Leopard II engines direct
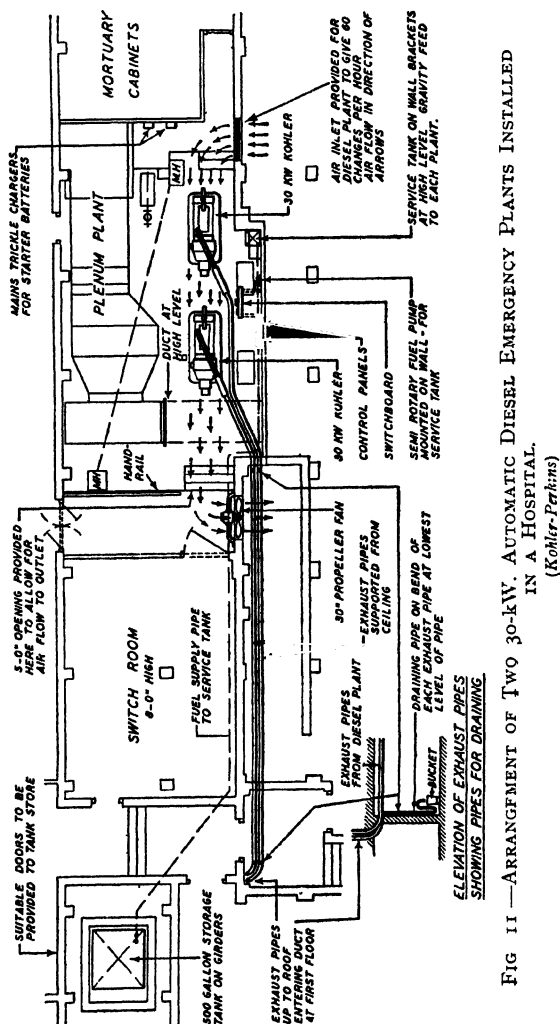
FIG 11 —ARRANGFMENT OF TWO 30-kW. AUTOMATIC DIESEL EMERGENCY PLANTS INSTALLED IN A HOSPITAL.
(*Kohler-Perkins*)

coupled to Crompton Parkinson alternators and exciters, each being equipped with Isenthal automatic voltage regulation to compensate for fluctuations in load.

These two plants are located in the basement of the hospital in a chamber also occupied by the Plenum ventilating equipment. In order to ensure that the plants are adequately cooled, a 30-in. circulating fan has been installed where shown, whilst an opening of similar size is arranged at the opposite end of the engine room.

Lighting Supplies.

The right-hand plant, which is of the fully automatic type embodying a patent system of operation, is arranged to come into action as soon as a mains failure of more than one second's duration takes place. Connected to it is a separate 230-volt emergency lighting circuit which runs throughout the entire building providing efficient lighting points in all important positions and corridors.

These lights are permanently connected to the output of this plant with the result that they become illuminated when a failure takes place without any action on the part of an attendant. Coupled direct to the generator, these emergency lights come up to brilliance as the machine gathers speed, full brilliance being obtained under normal conditions in not more than eight seconds from the period of interruption.

In order that the ventilation of the engine room shall also be automatic, the 30-in. fan previously referred to is wired directly to this plant in the same way as the emergency lighting, so that circulation of cooling air will also start at the same time as the plant.

Power and Lift Supplies.

The second machine, on the left of the first, is started by push button as this is primarily intended for furnishing current to power circuits such as ventilating plant, boiler motors, various electrical treatment devices and lifts, the latter being provided with creeping micro motors which are brought into use for emergency service, as these will take less power than any normal high speed lift equipment.

The output from both the plants is taken to the main switch room where, by means of change-over switches, the various load circuits can be fed from either the automatic or the push-button started plant and in this way maximum use can be made of the output of each machine.

As this system allows for the possibility of certain power circuits being switched on to the automatic plant under emergency conditions, it was decided that the automatic stopping usually furnished with this type of plant should not be employed in this installation. When mains are restored following a failure, it is naturally important that the automatic plant should not stop itself until all circuits which may have been switched on to it by hand have been transferred back to the mains.

It will be noticed that the cooling air passes first to the automatic plant and then after having been warmed by this plant, passes on to the power plant. To compensate for this the power plant is fitted with a tropical radiator whilst the lighting plant is fitted with a normal radiator.

An essential feature is that all doors to the engine room must remain closed, so as to ensure that the

circulating air will enter at the proper point and be discharged through the fan. For example, if the swing doors shown opposite the fan are wedged open the plants will be found to overheat because the fan will then draw air from the main corridor and eject it without passing it through the engine room.

Noise and Vibration Absorption.

Each plant is mounted on channels with "Silentbloc" rubber insulated bolts grouted into the concrete. This flexible mounting allows a certain amount of rocking movement of the machines as they are starting up or stopping and, during normal running, is very effective in reducing the transmission of sound from the machines to the floor and the rest of the building. When both plants are running there is no noticeable sound anywhere in the hospital except in the immediate vicinity of the machines and, as these are in the basement, it is quite impossible to detect whether the plants are running or not at any point in the hospital.

Fuel supply to the machines is provided in the first place from a service tank fixed in a corner near the automatic plant, and from this tank through duplex fuel filters the fuel is taken to each machine.

Fuel is fed to this service tank from a 500 gallon storage tank some distance away, a semi-rotary pump being provided near the service tank for filling. All the pipework connected with the fuel is ordinary black iron as galvanised pipe must not be used since the galvanisation is liable to be effected due to the action of the fuel oil.

Disposal of Engine Exhaust.

The disposal of the engine exhaust presents an

unusual problem in a very large building since the exhaust gases must ultimately be discharged above the roof. There is a strong possibility of sound being transmitted to the whole building if there is an exhaust pipe rigidly connected thereto and therefore special means were adopted in this case.

From the exhaust manifold of each plant, a 2-in. solid flexible pipe is taken in a quarter circle up to the silencer mounted on the engine room ceiling. The silencer is held in brackets but insulated therefrom with asbestos tape.

From the silencer the exhaust expands immediately into 15 ft. of 3-in. pipe, and from this point expands to 15 ft. of 3½-in. pipe, finally expanding to 4-in., at which size it continues right to the roof.

Throughout its entire length the exhaust pipe is supported on brackets from which it is insulated by asbestos tape, to prevent transmission of sound from the pipe to the upper parts of the building.

Better silencing is obtained by permitting gradual expansion, and the large diameter is also necessary to reduce back-pressure and the tendency to choke with carbon. In the products of combustion there is an appreciable amount of water produced and, whilst on a short exhaust pipe this is emitted in vapour form, in a long pipe, such as at the Westminster Hospital, the gases are considerably cooled, and the water vapour will be condensed.

To avoid damage to the engines which would result from the condensed water running back into the cylinders the exhaust system is trapped in two positions, a drop pipe being arranged where the pipes rise vertically to the top, and a secondary drop pipe in the

engine room itself at the lowest point of the horizontal run. Each of these drop pipes terminates in a "U" tube which acts as a trap and allows water to collect and escape but prevents the emission of exhaust fumes.

It will be seen therefore that the only part of the exhaust system which is not drained in this way, is that running from the silencers to the flexible tube to the engine itself. At this point the gases are sufficiently hot to ensure that condensation does not occur.

Starting Equipment.

Both plants are equipped with 24-volt C.A.V. type electric starting motors, of the type which contain a self-contained switch which is prevented from full engagement until a pinion is properly meshed with the flywheel gear ring.

These starting motors are brought into use by the closure of a pilot starting circuit; by push-button on one plant and by automatic control responsive to mains failure on the other. The latter plant also includes push-button starting as a standard provision, and either plant can be readily started by hand with the help of a decompressor.

The automatic starting system, for A.C. plants, which is protected by Patent No. 505306, is interesting in that the special means adopted enables the rapid starting qualities of the Perkins engine to be turned to full advantage. Fig. 12 shows details of the starting system.

When a mains failure of more than one second's duration occurs, a relay causes a 24-volt indicating lamp to be immediately illuminated from the starting battery. At the same time the pilot starting circuit is
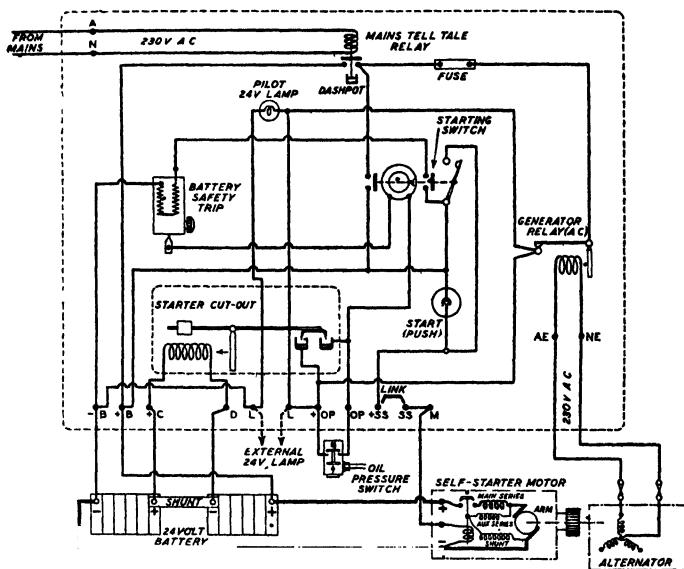
FIG. 12.—AUTOMATIC CONTROL ON KOHLER-PERKINS A.C. DIESEL-ELECTRIC EMERGENCY PLANT.

connected through an oil pressure switch whose contacts only remain closed when there is little or no oil pressure produced by the engine. This prevents effective completion of the pilot automatic starting circuit, except when the engine is stationary, or nearly so. In this way the automatic engagement of the starting motor (on a possible mains failure) is prevented, if the machine, after starting by hand control, has already commenced to run.

Once initiated, the starting circuit is locked against interruption due to mains restoration, so as to prevent the burning of the starting contacts which would result from interrupting the heavy starting current.

The establishment of the main starting current causes the oil pressure switch contacts now to be bridged by a polarised relay, which thus maintains completion of the pilot starting circuit, although the oil-pressure-switch will open after a few revolutions of the engine.

This polarised relay causes the starting motor to be held driving and accelerating the engine, until the starting current has fallen to about zero or just commences to reverse.

At this optimum point the relay opens and disconnects the starting motor. Right up to now the motor was assisting the acceleration, and any retention of the motor beyond this point would constitute a needless drag on the engine.

As soon as the alternator is generating, an A.C. relay interrupts the 24-volt control circuit, and so extinguishes the pilot lamp, and further interrupts the pilot starting circuit.

To protect the starting battery against exhaustion in an attempt to start without fuel, for example, a thermal trip switch will interrupt the pilot starting circuit (and thus disengage the starting motor) should the starting process occupy more than about three-quarters of a minute. The 24-volt indicating lamp then remains illuminated.

PUBLIC BUILDINGS, STORES, ETC.

The amount of emergency lighting provided in buildings of this type is usually much greater than in hospitals. Such buildings have been provided with emergency lighting batteries up to 230 volts, 900 A.H.; in fact one has a 230-volt battery of 1,600 A.H. capacity.

The fact that such large batteries are used for emergency lighting reveals the present-day importance attached to continuity of the lighting service. It is not so very many years ago that batteries no larger than this were used as part of the generating-station system on the main lighting service of a whole town.

Planning Storage Battery Emergency Lighting for Public Buildings.

For these larger buildings it is usual for the "continuous" type of automatic-switch system to be used, the lights under normal conditions forming part of the general illumination. Primary conditions to be settled are the division of circuits and the total load to be carried by the battery during an emergency. Two examples might show more clearly what is involved.

Example 1.—The ground floor of a building is to be used as a shop, and is to be served by one phase of a 230/400-volt, 1/3-phase standard 50-cycle supply. A section of the general lighting is to be selected and so connected that it is supplied from a 100-volt battery during a failure of normal supply. The load on the section is 2 kW., and the emergency period it is proposed to cater for is 3 hours; the "Keepalite" system is to be employed. Two kW. at 100 volts is 20 amps., which for 3 hours means a 60-A.H. battery at a 3-hour rating. For the 100-volt circuit, fifty cells would be employed. To supply the 100-volt circuit from the 230-volt A.C. mains under normal conditions a 230/100-volt transformer must be interposed, the output of this passing to the lighting load via a double-pole automatic change-over switch. The operating coil of this would be energised from the 100-volt A.C. supply,

which on failure would release the switch from its normal position, to change over under gravity or spring action to the emergency position, in which the 2-kW. lighting load is connected to the 100-volt battery. On resumption of A.C. supply the switch would automatically revert to its former position. The battery having been discharged, a switch on the control panel must be turned on to give a quick charge from a valve rectifier for a period appropriate for the amount of discharge. When fully charged again the battery must be left on trickle charge continuously. The same valve rectifier is used for both rates of charge by varying the amount of resistance in the charge circuit. Lamps form a convenient resistance for the trickle-charge circuit, which in this case would probably require not more than 75 milliamps. continuously to prevent the battery from losing its charge whilst standing by. The valves, although in continuous use, have a long life—several years—due to the fact that they are rarely used on full load.

The lamps on this special lighting circuit would be for 100 volts, otherwise the circuit is part of the ordinary illuminating system, and the lamps may be switched on locally. Usually it is advisable to arrange for them to be switched on in groups, and that it is the business of some definite person or persons to see they are switched on at dusk with the rest of the lighting.

Another Example.

Example 2.—Three floors of a large civic building are to be wired so that each floor selected lamps to a total of 5 kW. are wired on a special circuit, supplied
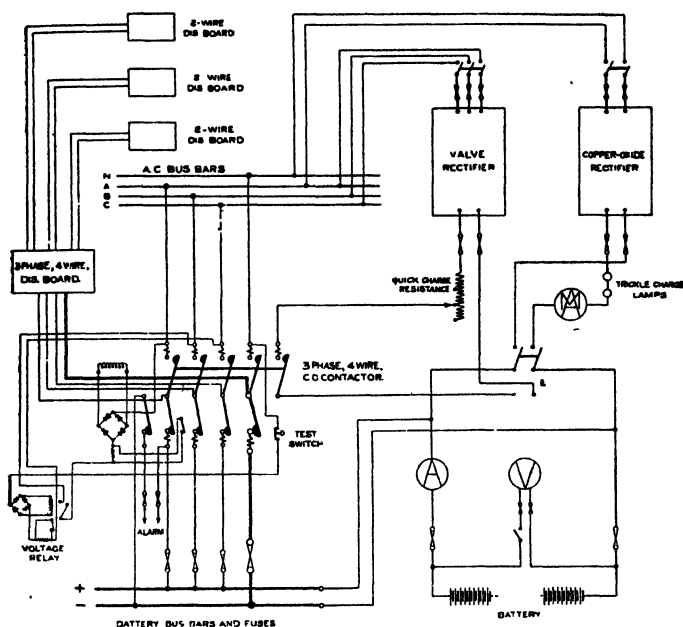
FIG. 13 — DIAGRAM OF THREE-PHASE "KEEPALITE" EMERGENCY LIGHTING SYSTEM FOR LARGE BUILDINGS.

normally from the mains and in an emergency from the battery. A 230-volt battery is to be employed, and the emergency period it is to deal with is 3 hours. The main supply is 230/400 volts, 1/3-phase, 50 cycles. All supplies are to be taken through 3-phase risers, and only one phase will be allowed for lighting purposes on each floor.

The total load on the special circuits is 15 kW., which at 230 volts is 65 amps., and the capacity of the battery is therefore 195 A.H. at the 3-hour rating. The number of cells usual for 230 volts is 115. Since

only one phase is allowed on a given floor, arrangements must be made that the same phase per floor is used both for the main illumination and for the normal source of the special circuit. Moreover, as 3-phase risers are specified, the circuit must be such that a 3-phase and neutral cable is carried up the building to supply the special circuits. Under emergency conditions this cable is so connected to the battery that the previous phases now become positive D.C., all in parallel, and the neutral becomes negative D.C., through the automatic operation of a 4-pole change-over contactor. A moment's thought will reveal that the "neutral" then has to carry the sum of the currents in the "phases". Hence, instead of the usual arrangement that the neutral is no bigger than one phase wire, it must have three times the section, and this proportion must be continued to the automatic change-over contactor.

At the different floors, distribution boards are connected to give the 2-wire services to the lighting points.

Owing to the size of battery and the charging rates involved in this example, it is better to employ a copper-oxide rectifier for trickle charging, and a separate valve-type rectifier or motor-generator for the occasional quick charge. It might be noted that another way to deal with the three phases is to provide three separate double-pole change-over contactors, one for each phase, all changing over to the battery, in parallel, when the supply fails. Such an arrangement involves a separate 2-wire connection to each floor, but in many cases this does not appreciably increase the cost of the cables required.

How a Battery is Maintained in the Fully Charged Condition.

An emergency or stand-by battery must always be maintained in a fully charged condition in order that the full capacity of the battery may be available on emergencies.

Normally the battery is kept continuously *trickle charged* at a very low rate, which is just sufficient to balance the loss of energy when standing on open circuit, but after an emergency discharge the battery must be given a quick recharge at the normal charging rate.

This is a method of maintaining a *fully charged* standing battery in the fully charged condition by passing a very small charging current continuously (i.e., *day and night*) through the battery. The current must just balance the losses (e.g., self discharge due to surface leakage, gradual sulphation, etc.) which occur in the particular battery on open circuit.

Trickle charging is *not* a method of recharging a partially discharged battery.

Advantages of Trickle Charging.

Trickle charging, when properly carried out, prevents any tendency for the electrolyte to combine with the active material of the plates. Thus the plates never become sulphated or sluggish and retain their full capacity for an indefinite period.

Very little supervision and maintenance is necessary for a stand-by battery on trickle charge, owing to the entire absence of heating and gassing of the electrolyte. There is in consequence no loss of acid and scarcely any wear of the plates through scrubbing action (which

occurs when a battery is gassing during a normal charge). Hence the life is far longer than that which would be obtained if the battery had to be worked under the usual cycles of charge and discharge to maintain it in good condition for emergencies.

The electrolyte retains its original specific gravity, and very little sediment, if any, is thrown down from the plates. For instance, in the 4,000 ampère-hour, 244-cell stand-by battery at the Bankside generating station of the City of London Electric Supply Company, the sediment, after 5½ years of emergency service and trickle charging, is insufficient to mark a clean stick.

Current Required for Trickle Charging.

The current required for trickle charging is very small—only a few milliampères in some cases—as a modern Planté type stationary battery does not lose more than 2 per cent. per day of its ampère-hour capacity at the 10-hour rate. Thus, with a 90-ampère-hour battery (10-hour rate) having an open circuit loss of 2 per cent. per day, the loss of ampère-hour capacity during 24 hours would be $\frac{2}{100} \times 90 =$ 1·8 ampère-hours, which must be compensated by the ampère-hours supplied by the charging current. Hence, the charging current = 1·8/24 = 0·075 ampère, or 75 milliampères.

In practice, the current is usually fixed slightly on the liberal side to take care of variations in the open circuit losses. The correct value may be ascertained by observation of the specific gravity, voltage, and gassing of the cells, as explained in the later paragraphs on maintenance.

How Trickle and High-rate Charging Currents are Adjusted.

The trickle charging current is adjusted to the required value by suitable series resistances (usually lamps), and the high-rate charging current is obtained by switching a resistance in parallel with the trickle charging resistance. Fig. 14 shows the general scheme of connections when a valve rectifier is employed.

FIG. 14.—HOW THE TRICKLE AND HIGH-RATE CHARGING CURRENTS ARE OBTAINED FROM A RECTIFIER

The trickle-charging current is adjusted to the correct value (read on the milliammeter) by the lamp resistances, *L*. The high rate charging current is adjusted to the correct value (read on the ammeter, *A*) by the resistance, *R*, this circuit being controlled by the switch, *S*.

Alternatively, a small valve, or preferably a copper-oxide, rectifier could be used to supply the trickle charging current, and a larger valve rectifier for the high-rate charging current.

The advantage of this arrangement is that the continuous trickle charge can be given very efficiently since the copper-oxide rectifier may be rated for no more than the trickle charge current, i.e., it will work on practically full load. There is a slight advantage in that an increase in the life of the valves is obtained, but it should be understood that modern gas-filled valves used for both trickle charging and occasional full-rate charging work normally at about one-fiftieth of their full load output and

experience has shown that under these conditions several years' life is obtained.

Where current is expensive the improved efficiency and somewhat longer valve life might easily pay the extra cost of the combined form of charger.

As the high-rate and trickle charging currents are obtained from separate circuits a double-pole change-over switch is necessary to change over the battery to the appropriate charging circuit.

AUXILIARY LIGHTING EQUIPMENT USING A NICKEL CADMIUM ALKALINE BATTERY

We give below details of a scheme devised by Messrs. Stuart Turner, Ltd., and Messrs. Nife Batteries, Ltd., for a standby or auxiliary lighting system suitable for use under emergency conditions.

Any period of darkness, however short, may readily induce panic, therefore any emergency lights should come into operation automatically and instantaneously.

This can only be achieved with safety by means of a battery associated with an engine-driven generating set.

Accordingly, the following description of an auxiliary lighting system incorporating some rather special features will be of particular interest to A.R.P. officers, police authorities, borough surveyors and engineers, fire officers, works and factory engineers, and all who are responsible for air-raid precaution schemes.

Conditions to be met.

Generally speaking, there are three distinct conditions:—

A. Where main supply is not available, or may be

inconvenient or too expensive to provide, and in the case of trenches or outside shelters, where damp and condensation are a source of danger in view of the high voltage.

B. Where main supply is in use and a low voltage emergency system is required when the mains fail.

C. Where it is desired to use one system of wiring only, with automatic transfer on mains failure to an alternative source.

In all cases a nickel cadmium alkaline battery and a petrol or benzole generating set form the heart of the installation, the control gear differing for the three conditions as follows:—

Condition A.

The control gear is similar to that required for a typical house-lighting or yacht-lighting installation. The battery feeds the emergency lights as and when required and the generating set is used for either charging the battery or taking over the emergency lights when the battery is discharged. The connections would be similar to those given in Fig. 16, but with the omission of the automatic switch.

Condition B.

The control gear is arranged in accordance with Fig. 16. It will be observed that under normal conditions the emergency lights are "off" and on mains failure they are *automatically and instantaneously connected to the battery.* As the usual size of battery has sufficient capacity to maintain the lights for a period of three hours, it is recommended that the generating plant should be started within an hour to allow for contingencies. The generating set will then take the

load and maintain the lights for as long as fuel is available. The generator can also be used for the recharge of the battery when conditions permit.

Condition C

Similar to that required for condition B, with the
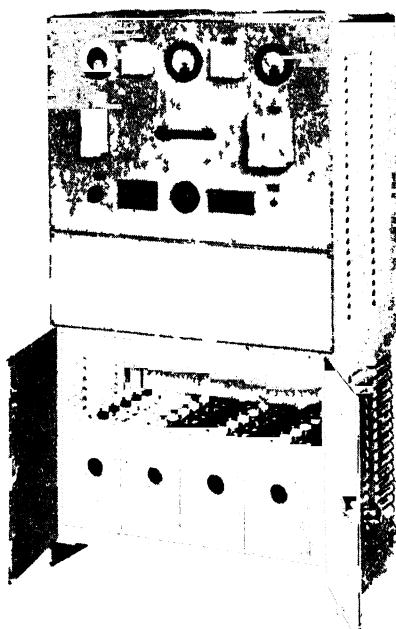
Fig. 15.—Nife Neverfayle Control Cubicle

exception that a step-down transformer is incorporated and the automatic switch is of the change-over type. Reference to Fig. 17 will show that under normal conditions the emergency lights are fed at reduced voltage (24, 50 or 100) from the mains via the trans-
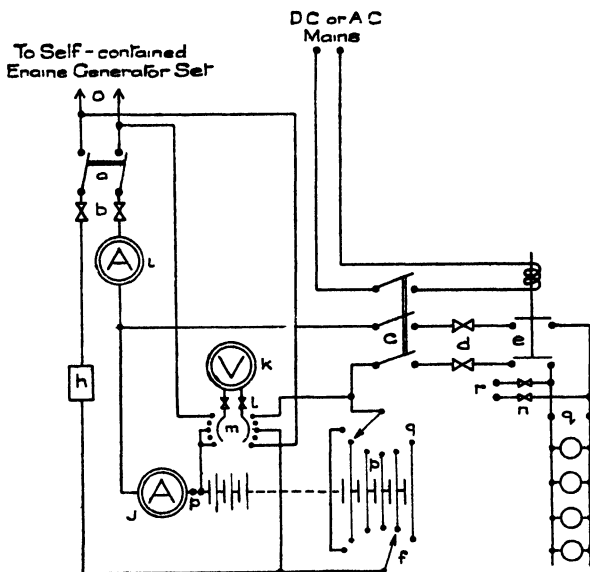
FIG 16—THEORETICAL DIAGRAM OF CONNECTIONS FOR SCHEME TO MEET CONDITION B

a, Charge switch, *b*, Charge fuses, *c*, Discharge and relay switch, *d*, Discharge fuses, *e*, Contactor, *f*, Charge regulator, *g* Discharge regulator, *h*, Auto cut-in and cut-out, *i*, Generator ammeter, *j*, Battery centre zero ammeter, *k*, Voltmeter, *l*, Voltmeter fuses, *m*, Voltmeter switch, *n*, Alarm fuses, *o*, Input terminals, *p*, Battery terminals, *q*, Emergency lighting terminals, *r*, Alarm terminals

former and on mains failure they are automatically transferred to the battery.

The Battery.

Unlike ordinary batteries, the nickel cadmium alkaline type is of all-steel construction employing an alkaline electrolyte. No corrosive fumes are given off on charge or discharge. The space occupied is small,
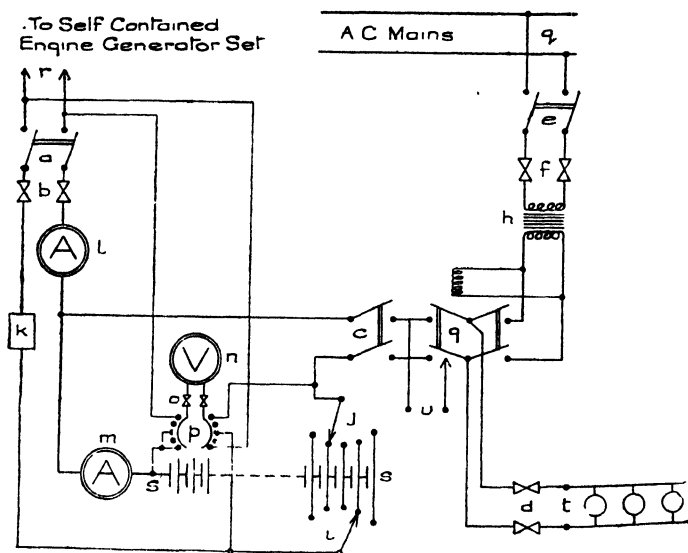
FIG. 17 —THEORETICAL DIAGRAM OF CONNECTIONS FOR SCHEME TO MEET CONDITION C.

a, Generator switch, *b*, Generator fuses; *c*, Discharge switch; *d*, Emergency lighting fuses; *e*, Transformer switch; *f*, Transformer fuses; *g*, Contactor; *h*, Transformer; *i*, Charge regulator; *j*, Discharge regulator, *k*, Cut-out; *l*, Generator ammeter; *m*, Battery centre zero ammeter; *n*, Voltmeter; *o*, Voltmeter fuses; *p*, Voltmeter switch; *q*, Main terminals; *r*, Input terminals; *s*, Battery terminals; *t*, Emergency lighting terminals; *u*, Alarm terminals.

hence the fact that it is accommodated in the lower compartment of the control cubicle (see Fig. 15). In sizes over 1 kW., however, the battery is mounted separately on a stand. This all-steel accumulator has further valuable qualities as follows:—

1. It is able to stand indefinitely without suffering any damage.

2. It is able to hold a complete charge for years without any attention.

3. The steel plates and containers are unaffected by violent concussion.

It will thus be seen that it fulfils all the essential conditions of an air-raid precaution battery which will be required to function instantaneously after, perhaps, years of storage and lack of maintenance.

A Stuart engine generating set provides the power for the system. These plants are used for lighting purposes in yachts and country houses and are equally suitable for A.R.P. auxiliary lighting. The engine runs on petrol or benzole, is of the two-stroke, three-port type, and combines high efficiency with utmost simplicity. The engine, being completely enclosed and gas tight, is perfectly clean and cannot leak or throw out oil.

The engine and the generator are mounted on a common cast-iron bedplate for easy fixing. Standard sets include tank cooling, but radiator-cooled sets can also be supplied. Standard ratings of the sets range from 300 watts to 3 kW.

The Control Cubicle.

The control gear and battery are accommodated in a floor mounting sheet-steel cubicle, the sides being "louvred" for ventilation of the battery. The lower compartment is fitted with hinged doors to provide access to the battery. The instruments and switches indicated in the diagrams are mounted on the panel.

The master control switch (British Patent No. 492,908) has six positions as follows:—

1. Equipment out of action.
2. Ready for emergency.

3. Generator supplying the lights with battery floating.
4, 5 and 6. Battery on charge, but equipment ready for emergency.

These switch positions apply to conditions B and C only. In condition A there are only four positions, 1, 2 and 3 as above, and one charging position with lights off.

Where an emergency lighting contactor is employed, this is fixed inside the control cubicle. Its operating coil is fed by D.C. either direct from mains or via a metal rectifier unit—this ensures silent and certain operation.

In the case of condition C, the double-wound step-down transformer is also fixed inside the cubicle. Terminal blocks for mains, generator, lights and alarm are mounted behind the control panel, so that they are easily accessible by removing a cover plate.

Complete control of the equipment is effected by the master control switch. This is termed unified control and is the salient feature of this emergency lighting system.

CHAPTER III

EMERGENCY LIGHTING IN THEATRES AND CINEMAS

AS mentioned in the previous chapter, in theatres, cinemas, concert halls and similar places of public entertainment a dual system of lighting from independent supply systems is compulsory by statute. This lighting must comply with the requirements of the local licensing authority.

Home Office Requirements.

The Home Office insists in its regulations: (1) that in any theatre or cinema there shall be an adequate number of safety or emergency lights which must be illuminated the whole time that the public is present in the building; (2) that these lights must be fed from a source which is entirely independent of that of the main auditorium lighting. In the majority of cases the main lighting is taken from the local electricity supply, which arrangement necessitates another separate source of supply for the safety lights.

London County Council Requirements.

In London the London County Council requires that in the auditorium or main hall the degree of lighting on each of the dual systems shall be not less than is sufficient to enable the public to see their way out of the premises at any time. In other parts of the

building to which the public has access, good general lighting must be provided, but on neither of the dual systems must the degree of lighting be less than is sufficient for the public to see their way out of the premises.

In the case of the majority of the London West End theatres a specially approved independent source of supply takes the form of a special "theatres main," which is entirely independent of the ordinary distribution network (from which the main lighting is taken) and is fed from an independent source at the sub-station.

How an Alternative Supply is Obtained.

Where such special mains are not available, a separate source of supply must be installed on the premises and for this purpose the storage battery is unequalled for reliability and economy.

Daily Recharge and Discharge System.

Under this system the storage battery which supplies the safety lighting must be capable of maintaining the full load on that system for at least twelve consecutive hours. Such a battery must be fully charged before the public are admitted to the building, and must not be recharged while the public are on the premises. Moreover, the circuits and switchgear must be such that the battery cannot be charged while it is connected to the lighting system. This system involves a large battery being subjected to the wear and tear of daily charges and discharges. Hence this system has almost entirely been superseded by the floating system.

In "floating" systems batteries are of a considerably

lower capacity than that indicated in the preceding paragraph.

The size of the battery is usually such that the full load on the lighting system which it supplies can be maintained for a period of three consecutive hours.

Floating Battery System of Supplying Safety Lighting.

A floating battery is one which, being fully charged, is connected in parallel with direct-current plant (generator or rectifier) and is normally inactive (i.e., it is neither discharging nor being charged), the voltage of the battery always balancing that of the generator.

Floating Battery and Rectifier.

The battery floats across a rectifier which is connected to, and normally supplies, the safety or secondary lighting system. The rectifier is connected to the A.C. supply system which supplies the main lighting.

In the event of the supply failing, the safety lights are supplied by the battery without any interruption of the lighting. Upon the restoration of the supply the lighting is again supplied by the rectifier, and the battery again floats across the rectifier. The battery must, of course, be recharged at the earliest opportunity. This recharging is effected from the rectifier.

End-cell Switches.

End-cell or regulating switches are necessary in the battery circuit for the purpose of adjusting the number of cells in circuit so that in normal operation the voltage of the battery balances that of the rectifier.

In some installations these switches are provided at *both* (positive and negative) ends of the battery in order that all the regulating cells may be brought into use by using the cells at the positive and negative ends on alternate days.
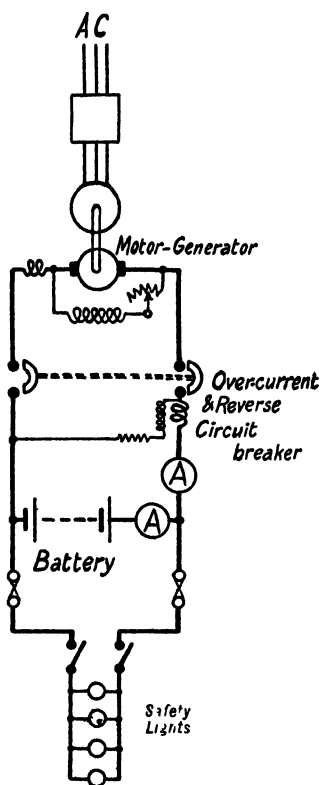
FIG. I.—FLOATING BATTERY AND D.C. GENERATOR SYSTEM OF SUPPLYING SAFETY LIGHTS.

NOTE.—The end-cell regulating switches are not shown.

Floating Battery and Generator.

Some local authorities allow the battery to be floated in parallel with a D.C. generator which is driven by a motor receiving power from the mains from which the main lighting is supplied. In this case a reverse-current circuit breaker must be provided in the generator circuit to prevent the battery discharging into the generator in the event of the failure of the supply to the driving motor. Fig. I shows the scheme of connections. End-cell switches are also necessary in this case.

The generator is adjusted to give its output at a voltage which gives a slight charge to the battery. Hence the battery dis-

charges to the lights only when the motor-generator set shuts down, and is therefore an emergency battery. Most county council requirements, under the Act, specify a battery large enough for a 3-hour emergency supply. The batteries usually have a nominal voltage of 100, though 50-volt and 230-volt batteries are also employed, depending on the size of the cinema.

Where the main supply is A.C., as nearly always is the case, rectifiers are employed to a much greater extent than formerly in place of motor-generators in floating-battery systems, such rectifiers being usually of the hot-cathode valve type, but occasionally of the mercury-arc type.

Typical Battery/Rectifier Floating System.

A typical diagram of a rectifier for this service, employing hot-cathode gas-filled valves, is shown in Fig. 2. A multi-wound transformer is used to change the main A.C. supply to the correct voltage for connection to the valves. There is a primary winding with tappings to suit any ordinary supply voltage, and there are two centre-tapped secondary windings, one for each valve. There are further secondary windings, also centre tapped, to provide the low-voltage supply to the valve filaments.

A delay switch is incorporated to ensure that the filament may heat up properly before any load is thrown on the valves.

The controls for adjustment of output usually consist of a transformer-tapping switch and an adjustable series resistance. In addition, there are the usual switches and fuses, and series relays are connected with coloured indicating lamps to show
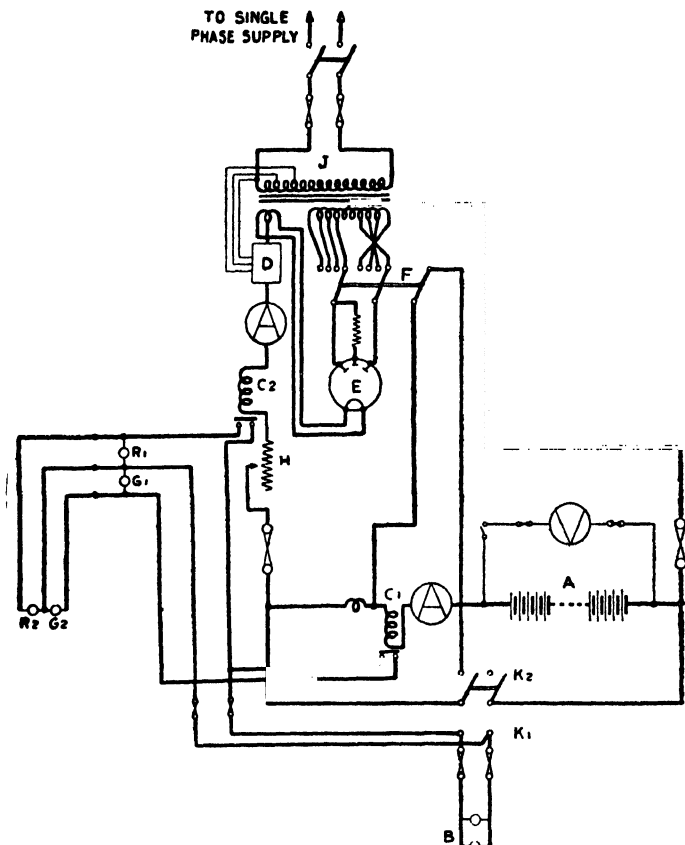
FIG. 2.—DIAGRAM OF FLOATING-TYPE BATTERY AND RECTIFIER EQUIPMENT FOR EMERGENCY LIGHTING.

A, Storage battery. *B*, Safety or secondary lights. *C*1, *C*2, Relays. *D*, Delay switch to allow filament to heat up. *E*, Full-wave hot-cathode valve. *F*, Regulating switch. *H*, Adjustable resistance control. *J*, Transformer. *K*1, Lights on. *K*2, Charging. *R*1, *G*1, Red and green signal lamps on the panel. *R*2, *G*2, Corresponding remote lamps.

when the rectifier is functioning normally or the battery is discharging appreciably. Whereas in the use of a motor-generator, in such a circuit, there must be automatic reverse-current circuit-breakers to disconnect the battery and load from the generator the instant the output of the latter fails, no such devices are necessary with rectifiers, which are inherently effective bars to reverse current from the battery. One disadvantage attached to the ordinary arrangement of rectifier is that, because of the inherent characteristic of the whole rectifier circuit, the output voltage changes as the load is varied. In some cinemas—particularly small ones—this does not matter, since the load usually remains constant, once switched on. In larger cinemas, with cafés attached and where parts of the premises are daylight lit until dusk (and do not under the regulations require safety lighting until then), there may be variations in the load. Such variations, in affecting the output voltage of the rectifier, also cause the floating conditions to be unsteady, and the battery may charge or discharge too much unless conditions are reset by hand regulation of the rectifier each time the load is changed. This, however, is not convenient, and the following system has been devised to overcome this difficulty.

Improved Rectifier for Floating.

The compensated rectifier (Brit. Patent 377671) is designed to maintain a substantially constant small trickle charge to a battery whilst the safety lighting load is being supplied on a parallel circuit. In series with the primary winding are two choke windings on separate iron cores, each of which also carries a D.C.

winding, these two being connected in opposition to cancel out any generation of A.C. by transformer action. These D.C. windings carry only the load going to the safety lights, and cause the iron of the chokes to be magnetically saturated to a greater or lesser degree, depending on the amount of load. Hence, the greater the load the greater the saturation, which causes the chokes to be less effective, so permitting a higher voltage across the actual primary winding and thus compensating for voltage drop that would otherwise take place. The reverse occurs as the load decreases, and by careful design the effect of the double-wound chokes is to maintain a practically constant floating voltage, so that the attendant may switch the lights on and off as required without any adjustment of the rectifier. In this design the delay switch is not required, owing to the effect of the chokes. This equipment is known as "Keepalite B" and is the invention of Mr. Basil Davis.

Other Types of Rectifiers.

Mercury-arc rectifiers are also employed, but are usually more suited to the larger plants of this type, particularly those having 230-volt batteries. The main details of the circuit would be the same as for the hot-cathode rectifier, except that there is no filament, nor filament winding or delay switch, but there must be a striking device to start up the arc. In all up-to-date rectifiers this starting is automatic upon the switching on of the A.C. supply. It is always necessary with manually adjusted floating-battery equipment to have very finely regulated control of the voltage round about the normal floating voltage.
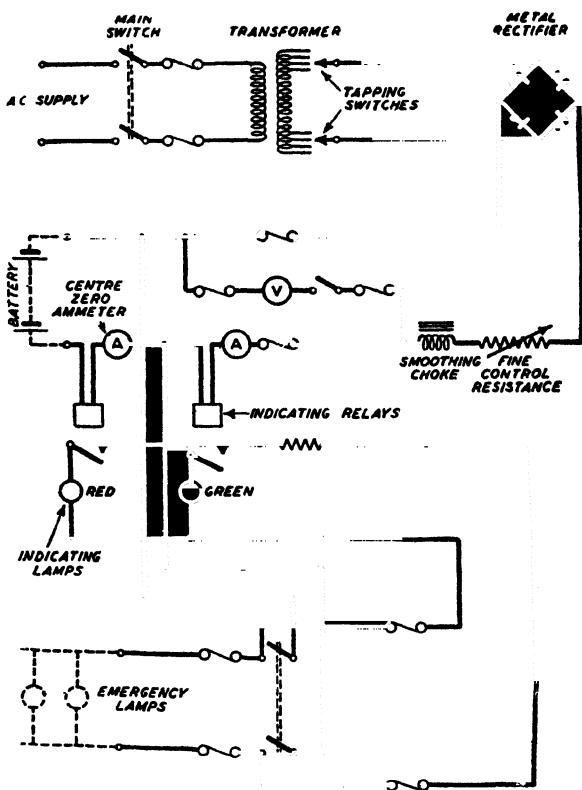
FIG. 3 —CONNECTIONS OF METAL RECTIFIER FLOATING BATTERY SCHEME.

The transformer-tapping switch and series resistance provide this for the hot-cathode rectifier, but in the case of the mercury-arc type, grid control is sometimes employed. The grid behaves in much the same manner as the grid of a radio valve, and very fine and efficient

TABLE I.—PARTICULARS OF BATTERIES FOR STANDARD CINEMA SAFETY LIGHTING EQUIPMENTS ("KEEPALITE" SYSTEM).

Equipment reference No.	*Number of cells.*	*Voltage of emergency lighting circuit.*	*Ampere-hour capacity of Battery.*			*Total load in kW. which the battery can supply for—*	
			1 hour discharge.	*3 hours discharge.*	*10 hours discharge.*	*1 hour.*	*3 hours.*
1	14	25	15	21	30	0·375	0·179
2	26	50	15	21	30	0·75	0·358
3	26	50	30	43	60	1·5	0·716
4	26	50	45	64	90	2·25	1·075
5	26	50	60	86	120	1·03	1·433
6	50	100	45	64	90	4·5	2·15
7	50	100	60	86	120	6·0	2·866
8	50	100	90	129	180	9·0	4·3

control is thereby secured without the use of moving contacts in the main circuit.

At present the copper-oxide or dry metal rectifier is not used to any appreciable extent for this type of duty, since, although an excellent rectifier, it is rather high in first cost.

TABLE II.—RATING OF TRANSFORMERS FOR CINEMA SAFETY LIGHT CIRCUIT, WITH BATTERY EQUIPMENTS GIVEN IN TABLE I.

Equipment Reference No. in Table 1.	1	2	3	4	5	6	7	8
Continuous Rating of Transformer (volt-amps)	200	375	835	1250	1500	2500	3000	4500

Trickle-charged Battery System of Supplying Safety Lighting.

In this system the safety lighting is normally fed from the public supply system which supplies the main lighting. But an *automatic change-over switch* is provided which will instantly switch the safety lights over to a stand-by battery, which is normally maintained continuously in the fully charged condition by trickle charging. After an emergency discharge the battery must be given a quick recharge at the normal rate.

The battery must be of sufficient size to maintain the safety lights for a period of three hours.

With an A.C. supply system, low voltage safety lights are used, which are normally supplied from a transformer.
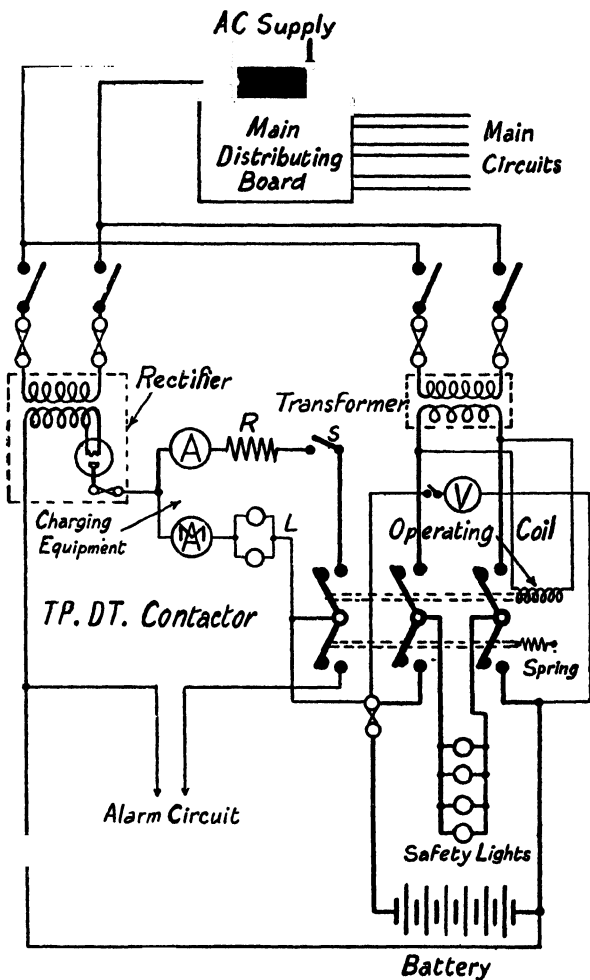
FIG. 4.—CONNECTIONS OF "KEEPALITE" A.C. CINEMA EQUIPMENT.

This system is used in a large number of provincial theatres and cinemas. Particulars of the batteries for standard equipments are given in Table I, and the ratings of the transformers for these equipments are given in Table II.

With a D.C. supply system, however, the safety lights and the battery supplying them must be suitable for the mains voltage. Difficulties may then be encountered in the charging arrangements unless a three-wire supply system is available.

Connections of "Keepalite" Cinema Equipment for A.C. Mains.

Fig. 4 shows the connections of a standard cinema equipment in which a transformer is used to supply the safety lights. In all these cinema equipments the automatic switch takes the form of a triple-pole double-throw contactor, two of the poles being used for switching the safety lights from the transformer to the battery, and the remaining pole for switching the charging circuit and controlling an alarm circuit.

How the Automatic Switch Works.

The operating coil of the contactor is permanently connected across the secondary winding of the transformer which normally supplies the safety lights. Hence, as long as this supply is maintained, the armature will be attracted to the pole piece, the upper moving contacts will make contact with the upper set of fixed contacts, and the lower contacts will remain open. Thus the safety lights will be supplied from the transformer, and the battery will be trickle charged all the time that the main supply is maintained on

the operating coil. But immediately this supply fails, the contactor will drop over to the lower contacts, and the safety lights will be connected to the battery. At the same time an alarm circuit will be closed to indicate that the main supply has failed. When the supply is restored the contactor will switch the battery over to the charging contacts. The battery may then
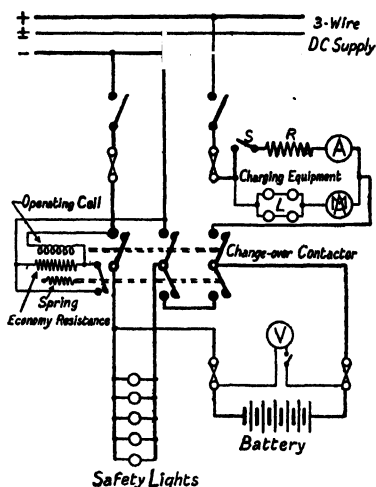
FIG. 5.—CONNECTIONS OF "KEEPALITE" D C. CINEMA EQUIPMENT FOR THREE-WIRE SUPPLY.

be given a high-rate charge, if necessary, by closing the "charge" switches.

The trickle and high-rate charging currents are indicated on separate ammeters.

Equipment for Three-wire D.C. Mains.

Fig. 5 shows the connections when a three-wire D.C. supply is available. In this case the safety lights are

normally connected between one of the outers and the neutral, and the battery is of this voltage. Charging is effected from the outers of the supply system.

The trickle-charging and high-rate charging circuits are arranged similar to those in the A.C. equipment, but the series resistances are of higher value.

In order to reduce the energy consumed by the operating coil, the winding of this coil is designed so as to close the contactor when it is excited with the mains voltage, and, after closing, a resistance is connected in series with the winding to reduce the current to such a value as to hold the contactor in the closed position.

An auxiliary switch is required on the contactor to short-circuit this resistance when the moving contacts of the contactor occupy the lower position (i.e., when the main supply is "off", and the safety lights are supplied from the battery).

CHAPTER IV

INSTALLATION OF PRIVATE GENERATING SETS

MOST small lighting plants are used for establishments where space is not severely limited, and this is as well where a battery-charging set is concerned, since the room needed is considerable. Whatever the type of set, however, it is a mistake to economise too much on room and installation expense if the best results are to be obtained.

Location of Engine House.

Frequently it is necessary to use an existing shed or stable on account of cost, and sometimes such buildings are quite satisfactory; but more often it is found that they are poorly ventilated and lighted and that they do not allow of adequate space being provided round the plant bed.

In deciding where to place a new engine house the first consideration is the question of noise, and next the distance from the building to be supplied: with a low-voltage set the large cables necessary to prevent undue voltage drop form a big item in installation expenses. Although engine silencing is more efficient than it was, even a quiet exhaust is extremely irritating at night, and the growing use of automatic plants has resulted in an increase in night running of the engine.

FIG. 1.—VIEW FROM GENERATOR END OF $8\frac{1}{4}$ kW DIESEL ENGINE-DRIVEN SET 210 VOLTS, D.C., INSTALLED AT A LONDON BANK

Space required for Batteries and Set.

If a set is to be installed with batteries of the open-top type a separate room is necessary for the cells. Both engine and battery houses should have windows that open. The set should be installed with a space

of at least 2 ft. clear all round it so that there is easy access for overhaul and inspection. The height of the engine-room ceiling over the bed must allow of the piston being withdrawn without difficulty, and in the case of larger plants it may be necessary to have room for lifting-tackle to handle a flywheel or dynamo.

INSTALLING ENGINE AND DYNAMO

Independent Mounting or Combined Baseplate?

A concrete bed should be put down for the set, and the question of whether the engine and dynamo should be on a combined base or arranged for independent mounting on separate foundations depends largely on the size and type of plant. With small sets of up to about 5 kW. output a baseplate is the rule whether engine and dynamo are direct coupled or with belt drive, but on plants above this size it is the exception. The combined baseplate is an obvious advantage for easy installation.

Where a belt drive is taken for the dynamo it must be from the side of the engine pulley nearest the fly-wheel to reduce strain on bearings and crankshaft to a minimum.

The general layout of the engine room will be governed by the requirements of the cooling and exhaust systems, which must depend on external factors.

Size of Foundation.

The actual design and dimensions of the lighting-plant bed will be given on the maker's installation drawing, but it should be noted that such particulars
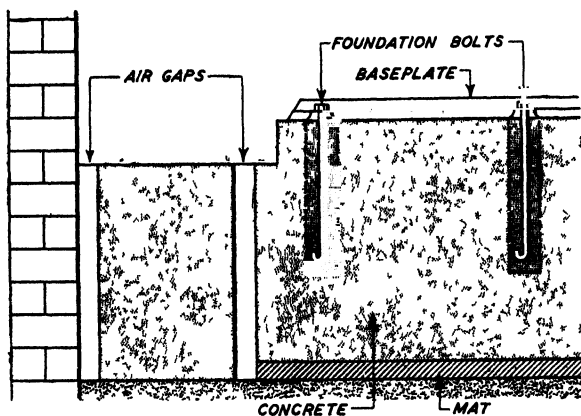
FIG 2 —SPECIAL ANTI-VIBRATION ENGINE BED.

are based on the assumption that the ground is of a normal firm nature. Should the plant be installed on made-up ground or on a floor with space underneath, the size of bed and its depth must be reconsidered. The precautions will vary according to the size and type of set, but it is often possible to carry the plant on channel girders embedded in concrete.

Insulating Mat between Concrete and Engine Bed.

Some makers recommend the use of an insulating cork mat on a concrete bed carrying the engine bed on it as a check to the transmission of vibration, and small plants have also been installed on a rubber Sorbo mat inserted directly under the baseplate and with rubber bushes round the foundation bolts. The former arrangement is shown diagrammatically, and it will be noted that as a further precaution against transmitting vibration there is a space left round the engine room.

Foundation Bolts.

The type and length of foundation bolt vary with the size of set, but the majority of makers supply hook bolts, which in the case of small sets may be about 9 in. long, rising to, say, 21 in. in plants of from 15 to 20 kW.

Making the Plant Bed.

The best composition for the engine bed is concrete, made up of one part of cement to two parts of clean sand and four parts of 1-in. screened and well-washed stone or gravel. The concrete must be very thoroughly mixed before use. In making the bed the first work to be done is the digging out of that portion which is sunk below floor-level to the given dimensions, care being taken to keep firm walls to the pit. A wooden frame should then be made to hold the concrete above floor-level while it is setting, and this frame must be soundly constructed, with its sides parallel and of the full height required. There are also four or more wooden casings to be made, which will be inserted while the bed hardens and will then be withdrawn for the foundation bolts to be put in. These bolt boxes or tubes must be long enough to form holes for the full length of the foundation bolts, bearing in mind the thickness of the iron or steel baseplate which rests above the concrete and on which the holding-down nuts will have to be tightened. The bolt chases will be 3 or 4 in. square.

When the wooden frames are ready in position the concrete can be poured in, and before filling it is advisable to check the position of the bolt boxes. The concrete should be left at least a week to set before

Fig 3 —Lister $3\frac{1}{2}$ kW Diesel Engine driven Automatic Plant

the plant is installed. The bolt boxes can then be taken out, the outside frame removed, and the bed is ready for the set.

Erecting the Plant on Bed.

The engine, or engine and generator on their combined base, should now be lowered carefully on to packing pieces, placed on the bed to a height of about an inch, close to each foundation bolt. These packing pieces should be about 2 in. wide by about 8 in. long and of wrought iron. It is essential that the baseplate should rest absolutely level on them, and this must be tested by spirit-level. When the level has been adjusted by the use of packing strips of varying thicknesses, the foundation-bolt nuts can be screwed up flush with the ends of the bolts and the set checked for alignment. If the engine and dynamo are direct-coupled it is most important that both are levelled up accurately if no baseplate is used. The faces of the coupling must be checked, before inserting the coupling bolts, by means of feeler gauges. The engine should be turned over slowly by hand and a test made at several points to ensure equal gaps in any position and that the centres of the two shafts are exactly the same height.

When level and alignment are satisfactory the foundation bolts can be grouted in. The grouting mixture consists of one part of cement to two parts of fine sand; it should be allowed a couple of days to set before the nuts on the foundation bolts are evenly tightened down. Alignment should then be checked again, as it is easy to spring a bedplate in tightening

down and so upset alignment: such a disturbance might later result in a broken crankshaft.

The bedplate itself can now be grouted in with the same mixture, and this will necessitate a further wood casing being made to stand just above the bottom of the engine baseplate to hold the grout. When this is set and the casing removed, the bed should be finished off by rounding all edges and corners with a rich cement-and-sand mixture, and the block itself plastered with the same finishing compound.

INSTALLING COOLING SYSTEMS

Tank-cooling System.

Most small lighting plants have engines arranged for water cooling with one or more galvanised tanks. The quantity of water necessary in this country is normally reckoned at about twenty gallons per B.H.P., but it is standard practice to use tanks of at least 25 per cent. larger capacity than normal for lighting sets, on account of the relatively long hours for which they run and the load being heavy and continuous. If at any time there are signs of overheating the temperature should be tested, and it may be necessary to add water to keep within a safe limit, which can be taken as 130° F.

The position of the tank relative to the set will depend partly on the individual layout, but it is desirable to have the tank close to the engine, although outside the engine room when possible. Tank cooling is usually on the thermo-siphon principle, and the inlet pipe to the engine cylinder should be approximately horizontal, with a steady rise on the outlet

pipe from the cylinder head to the tank. If a water-circulating pump is fitted to assist circulation the position is, of course, less important, but this is seldom done on a small set.

The water-level in the cooling tank must never be allowed to fall below the level of the engine outlet pipe, or thermo-siphon action will be stopped and the engine will rapidly overheat.

Radiator Cooling.

It is becoming increasingly common to find sets with radiator cooling either arranged for thermo-siphon action or, more usually, pump-assisted. The chief advantages of a radiator-cooled set are its being self-contained and occupying little floor space. Incidentally, in comparison with a tank-cooled set the small closed circuit of the radiator requires very little anti-freezing mixture where this is necessary.

Air-cooled Engines.

Although air-cooled engines have the advantage of simplicity they are not popular for lighting plants, on account of the risk of overheating with the long hours and the fact that they are undoubtedly noisier than the water-jacketed type.

Installing Radiator-cooled Set.

Radiator-cooled sets are sent out ready for installation, the radiator being mounted and the drives to the fan and pump being arranged.

Installing Tank-cooled Set.

On a tank-cooled set there is no point likely to cause difficulty, but a 3-way cock should be fitted in the

bottom water connection so that the whole system, or alternatively the engine jacket only, can be drained in frosty weather or during an overhaul. When the tank is outside the engine room this cock should be outside also, in a convenient spot for the water to run to waste. The tank is usually mounted on a concrete plinth or brick piers.

When filling up the tank in the first instance, and in any subsequent making up, rain-water should be used; it is worth going to some trouble to keep a supply available. Hard water will result in scale being formed in the engine-cooling jackets, and if allowed to continue will mean serious trouble due to overheating; scale up to, say $\frac{1}{16}$ of an inch is permissible, but it should never be allowed to increase beyond this limit.

INSTALLING FUEL SYSTEMS

Erecting Tank.

Gravity feed is almost universal for fuel systems, and the makers usually provide a tank of sufficient capacity for about eight hours' running. This is arranged to mount on brackets on a wall, and the head above the pump or carburettor should normally be between 12 and 24 in. If the head is too little or too great the adjustment of the fuel system on the engine may be upset.

Making Tank-to-engine Connection.

The pipe from the tank to the engine connection should be arranged with a coil in it near the latter, but otherwise as straight as possible, either sloping gradually down to the engine or with one vertical drop and then horizontally. The aim is to prevent

air locks, and a careless installation soon causes these to occur. The pipe should be clipped to any convenient point, as near as possible to the engine beyond the coil mentioned, to prevent vibration being transmitted along its length.

Installing a Fuel-storage Tank.

The average private installation does not require a main fuel-storage tank, but where a larger set is being installed for which the fuel consumption is considerable, a tank is worth while to enable fuel to be purchased in economical quantities. Such tanks are usually installed outside the engine house in a convenient position for the filling lorry to reach them. They can be underground, but are more usually mounted on brick or concrete piers above ground-level.

A galvanised tank is not suitable for fuel oil, as it is liable to scale and there is the danger of such scale passing the filters and reaching the pump, thus injuring its delicate mechanism. The tank should be of steel plate, welded or riveted and provided with dip rod, vent, and drain cock. The draw-off connection must be above the actual bottom of the tank, allowing dirt to settle there without being drawn off. The most satisfactory arrangement is to fit a hand-pump of the semi-rotary type in the engine room for supply to the small service tank mentioned above, which can then be filled daily. Incidentally, it is as well to use a tank of 24 hours' capacity with automatic plants.

EXHAUST SYSTEMS

The exhaust layout is of paramount importance, and if wrongly designed in the first place may be the

hidden cause of many subsequent troubles. Most engines are supplied with some form of silencer, either for insertion in the pipe-line or bolting direct to the cylinder, but in addition it is usually necessary to fit another silencer or to carry the gases to an exhaust pit. Piping size will vary with the type of engine, and the maker's recommendation should be obtained and their approval sought for any unusual or involved system.

Size of Piping.

The risk of back pressure due to too small a pipe or a layout having too many bends before the gases can expand to atmospheric pressure is greater if the engine is a two-stroke. Investigation with this class of engine has shown that the whole running of small sizes is bound up with the exhaust system, and exhaust piping which is too long or too short can affect power output and fuel consumption considerably. There was recently placed on the market the first engine to use the pressure waves which are created in an exhaust system as a means of scavenging burnt gas from the cylinder, and the length of exhaust pipe and type of silencer for this unit cannot be varied from those which experiment and calculation alike have found to be the most efficient.

Silencing the Exhaust.

When the pipe diameter has been decided upon the choice must be made between carrying the pipe direct to the atmosphere or discharging first into another silencer or an exhaust pit. If space allows, the latter arrangement is cheap and efficient, but where there
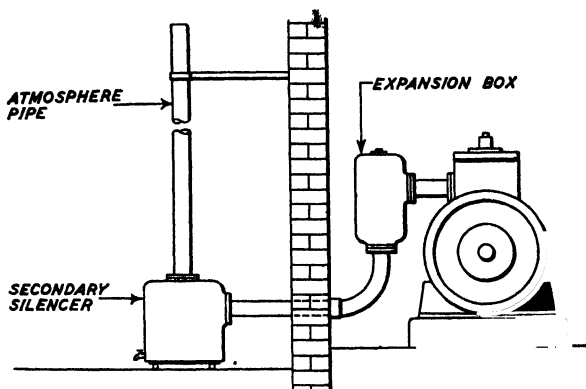
FIG 4.—EXHAUST SYSTEM WITH SECONDARY SILENCER.

are restrictions, due to neighbouring buildings or the like, a secondary silencer may be used, either of the cast-iron pot type or of a proprietary make such as the straight-through Burgess, shown in section.

Fit Drain Tap.

The exhaust system must in any case be designed so that no sharp elbows and as few bends as possible are used. It is essential that it should be arranged with a drain tap at its lowest point, so that it is a simple matter to drain out any condensation of water (this always occurs to a certain extent in any system) and also any unburnt oil that may accumulate. If a system is not easily drained such oil or water may get back to the cylinder, or the oil may accumulate to such an extent as to cause a fire.

Where an exhaust pipe passes through a wall it must never be cemented in: the pipe should be free for expansion and easy to dismantle for cleaning.

Making an Exhaust Pit.

If an exhaust pit is used the gases should be led from the engine through the maker's silencer if supplied, and then taken out in a trench under the floor to the side of the pit. The trench should be deep enough to allow of cleaning out under the pipe, and loose chequer plating is the most satisfactory cover when the length of pipe and class of installation warrant it. The actual
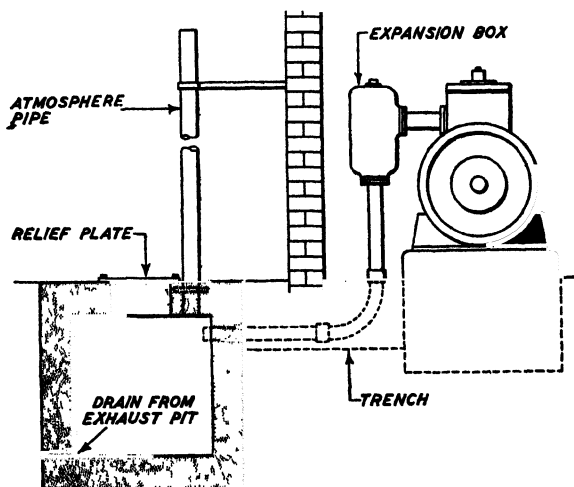
FIG 5 —EXHAUST SYSTEM WITH PIT SILENCER

pit dimensions vary again with the type of engine, but broadly a plant of less than 5 kW. would use a pit about 36 in. square and deep, and a plant of less than 20 kW. a pit of 48 in. square and deep. The pit sides should be of concrete 6 in. thick, and if it projects above ground the sides should be reinforced. The top can be covered with a loose concrete slab or fitted

with a relief plate. This consists simply of an iron plate held down by springs, the compression of which is sufficient to keep it in position against any normal pressure. Some makers recommend the pit being divided into two or three parts by internal walls with connecting holes.

Draining Pit.

Whether a pit can be drained or not depends on the site, but if at all possible a drain pipe should be arranged, as there is an inevitable accumulation of condensed water and oil. If no drain can be arranged from the pit bottom a manhole must be fitted for cleaning, or the relief plate made large enough to serve the purpose.

The atmosphere pipe (i.e., the pipe leading from the exhaust pit or silencer to the atmosphere) should carry the spent gases well above the eaves of the building. It will require staying to the wall and should terminate in a cowl. This pipe is of slightly larger diameter than the pipe from engine to pit or to silencer.

Three or four inches of standing water in the pit with the inlet pipe coming in below water-level are an added safeguard against fire and improve silencing.

Connecting up Exhaust Piping.

In connecting up exhaust piping, flanged joints are preferable to socketed ones, although considerably more expensive. The flanges are easy to assemble and strip down, and they neither become so hard to disconnect nor leak so easily. Jointing can be quickly beaten out of asbestos sheet.

CONNECTING UP

The erection of the batteries is dealt with in chapter V. Before the battery can be given its first charge there are several points on the set to which attention has to be paid, including connection of the set and control switchboard.
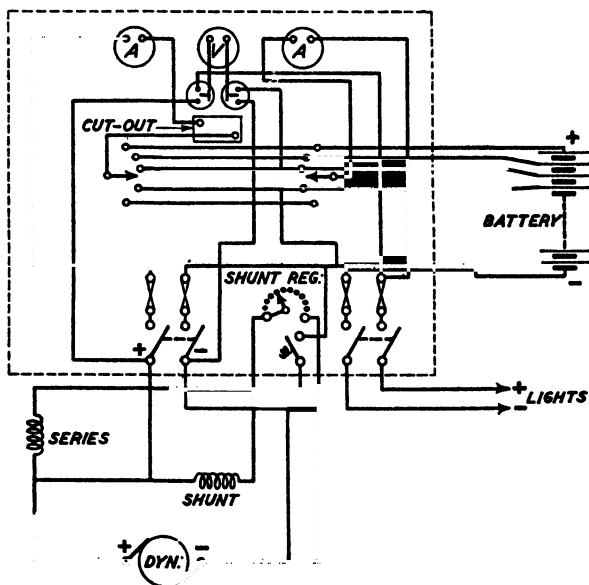
Fig. 6.—Diagram of Wiring on Typical Battery-charging Board.

Wiring of Control Switchboard.

The actual wiring of the board will depend on the type of set in question, and wiring diagrams will be provided by the plant makers, who will supply the panel with all small back-of-board wiring done. There

remain the cables from the dynamo to the board for connection, and these are best carried in steel conduit under the floor to the wall and then over insulators.
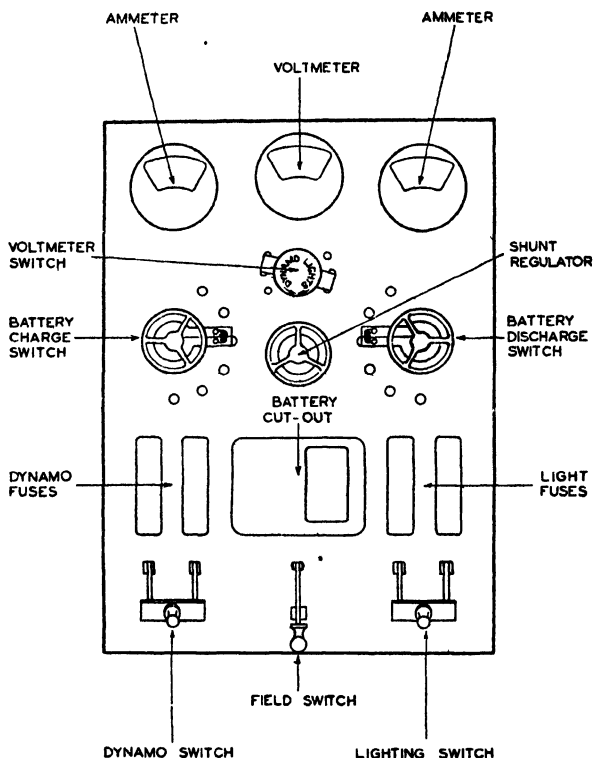
FIG. 7.—LAYOUT OF TYPICAL BATTERY-CHARGING SWITCHBOARD.

Cable ends must have soldered-on terminals to make really satisfactory connections. The board wiring for either straight battery charging or direct-lighting

sets is simple enough, but for automatic plants it is complicated by the controls for such purposes as relieving engine compression when starting, electric governing, safety cut-out, and the like.

On battery-charging sets the shunt-wound dynamo is usually fitted with series turns for starting, when it is used to motor the engine. This arrangement is sometimes described loosely as semi-automatic, since the starting is not by hand, but by the spring-controlled starter switch being held in position until the engine fires.

Filling Mercury-cup Contacts.

On most lighting plants the automatic cut-out which prevents a reversal of current from battery to set is fitted with mercury-cup contacts. The mercury should be filled to within $\frac{3}{16}$ in. of the top of the cup before starting.

Checking Polarity of Dynamo.

The polarity of the dynamo should be checked before connecting up, and this is done by immersing the cable ends in a jar of water when the set is running. The negative lead will give off a stream of small gas bubbles.

Connecting up Battery.

In connecting up to the battery it should be remembered that the negative plates are grey and the positives are chocolate colour. The negative lead from the board is, of course, connected to the negative battery terminal.

STARTING UP THE PLANT

Test Engine Rotation by Hand.

Before actually starting up the engine it should be turned round slowly by hand to ensure freedom from any physical obstruction.

Check Lubrication.

Be sure that the lubricator is filled to the correct level, and if a priming device is fitted—use it.

Where main bearings are oil lubricated, examine the level in the oil wells, and if grease lubrication is employed use the gun once on each nipple or give the greaser a turn, not forgetting the dynamo bearings in either case.

Attend to Fuel System.

The fuel system will require freeing from air, and where a fuel pump is fitted this is done by moving the pump control to give the maximum fuel injection, slackening off the delivery union on the atomiser, and turning the engine by hand until oil appears at the atomiser connection. The union must be well tightened again, and indeed all union nuts, sockets, flanges, and joints should be gone over to check leaks of oil, fuel, or water.

Tightening down after Starting.

This tightening down must be repeated after starting, as the influences of heat and vibration result in any slack nuts rapidly becoming slacker on cooling again. The cylinder-head nuts in particular should be examined and tightened regularly the first half-dozen times of running.

Test for Overheating.

On the engine and dynamo, bearings should be felt for signs of over-heating and a check made that oiling rings, where fitted, are rotating freely.

The individual feeds on lubricators should be checked against the maker's recommendations and adjusted where necessary.

When Sparking Occurs.

The dynamo commutator should be examined, and, if sparking noticeably, brushes may need bedding down or the brush position require adjustment. If the machine is not running up to its full voltage or output suspect the meters, which are frequently damaged in transit, or, if these are correct, faulty connections are likely. The automatic cut-out on a battery plant should make its contact cleanly without hesitation or arcing, and if it does not do it should be readjusted at once.

CHAPTER V

BATTERY INSTALLATION

WITH many sets of the automatic type, portable or semi-portable batteries are supplied, and these are often erected simply on wooden battens on the floor conveniently near the set. It is more satisfactory, however, to use wooden trays or crates with lifting handles, as these make a neater and more easily moved installation.

Battery Stands.

With stationary batteries, such as are used in all bigger sets, and in cases where expense is not of primary importance, the cells are mounted on wooden stands of one, two, or three tiers or on stillage. It is usual to let the battery makers supply this equipment in view of their facilities for cheap manufacture, but if supports are to be made they should be of seasoned timber painted before and after erection with anti-sulphuric acid enamel. No metal whatever must be used in their construction. In the case of double- or treble-tier stands the height of upper shelves must allow of plates being easily removed from the lower cells. The height of the cells should be such that inspection is convenient, and for this reason single-tier stands are best where they can be used. Stillage consists of longitudinal bearers resting on cross-pieces,

FIG 1 —THE BATTERIES FOR THE AUTOMATIC LIGHTING INSTALLATION AT FLITCHAM, NORFOLK

which are carried on insulators, but this arrangement is generally found only with larger batteries.

Space should be allowed, if at all possible, on both sides of battery stands, and lighting should be adequate for inspection of every cell. As mentioned above, a separate room is a necessity for open-top type batteries, and good ventilation is essential.

Dealing with Open-top Batteries.

Open-top batteries of the sizes under consideration are sent out with connecting bars ready burnt on to the plate lugs, and as it is not uncommon for lugs and bars to be bent in transit, they must be straightened before erection. It is easiest to do this before unpacking the plates, when they are still held tightly in their packing. Care must be taken to ensure that plates are central in their boxes and in line, and that the supporting lugs stand clear in adjacent plates, as otherwise shorting will occur. The section lugs are right- and left-handed alternately, and in placing the cells in position the positive lug of each cell must come in juxtaposition with the negative lug of the next.

When all the cells are in position the connecting bolts can be fitted and each cell aligned with its neighbour. It is better to have cells slightly out of line in the row rather than throw undue strain on lugs in bolting up, but the appearance of a battery depends on alignment being maintained as far as possible.

See that Cells are at Same Level.

It is necessary to make sure that the cells are at the

same level throughout the row, and this can be adjusted by the insertion of lead discs on the insulators on which each cell rests. If boxes are incorrectly levelled there is strain, tending to lift some lugs; after connection the separators can be inserted, also the end springs which hold the section tight in its container. Connecting bolts and nuts must be clean and thoroughly coated with vaseline to prevent corrosion from acid spray.

After Erection.

After erection is completed a check should be made for alignment, tightness of connections, and shorting through lugs touching. Acid must not be added until the battery is ready to be charged and all connections made, as sulphation will occur if the cells are filled before the first charge can take place. The two unconnected lugs will, of course, be positive and negative respectively and must be connected up accordingly to their corresponding switchboard terminals.

Filling with Acid.

When everything is ready, acid can be put in the cells. An earthenware jug should be used for the purpose, the level in each cell being at least half an inch above the plate top. A metal jug or bucket must never be used for acid. The acid may be supplied in concentrated form, and if so must be mixed with distilled water to the required specific gravity: a hydrometer is supplied by the battery makers. The mixing is best done in an earthenware vessel, and the acid must be added to the water—on no account add

water to acid. Stir well and take the specific gravity at a temperature of 60° F. The heat that occurs in mixing is considerable, and great care must be exercised. The diluted acid should stand for some hours after mixing. In the event of the acid having to be made up the details given in Table III will be found helpful, as the relative quantities of water and acid are given for various solution gravities.

The First Battery Charge.

When all cells are filled the first charge can begin and will take some sixteen hours on a previously "short first-charged" battery. Closed-top cells are sent out in a fully charged condition. It is best to have the first charge long rather than short, and in any case it cannot be completed until all cells are gassing freely from both positive and negative plates. The specific gravity will increase to about 1·240 and the voltage reading to about 2·7 volts per cell while the battery is being charged. The charge should continue for some 3 hours after the specific gravity has become constant. No discharge must be taken until the first charge is finished, and if this cannot be completed in one day it must be finished with the minimum of delay. Following the first charge the battery should be overcharged one hour at least on each of its next dozen charges

Bare copper wire is usual for inter-row and connecting leads and regulating leads, and an otherwise neat installation can be spoilt by careless bending; all bends should be in the same or a parallel plane or at right angles, and a sharp bend is better in appearance than a more gradual one.

TABLE III.

PROPORTIONS OF ACID AND WATER REQUIRED FOR DIFFERENT STRENGTHS OF ELECTROLYTE

One part of concentrated sulphuric acid—S.G. 1·840 approx.—must be added to the listed parts by volume of water.

Required Gravity.	*Parts of Distilled Water.*
1·150	6·52
1·200	4·60
1·210	4·33
1·230	3·84
1·250	3·43
1·300	2·64

Note.- -Final gravity cannot be easily settled until mixture has cooled down.

CHAPTER VI

WIND-DRIVEN LIGHTING PLANT

THE idea of obtaining electrical energy from the wind virtually at no cost at all, beyond that expended on initial outlay for equipment, has always been attractive. The principal field of use for wind-driven electric lighting plant is in connection with bungalows, sports pavilions, farm buildings, or in fact, any buildings which are remote from electric supply mains, and where the demand for current is so small as to make the cost of an engine-driven plant prohibitive.

Some Advantages.

Before describing one of the best known makes of wind-driven generators, and its method of installation, it will be of interest to refer to the many advantages provided. In the first case the initial cost is really quite low, while there are no running expenses. No expert attention is required, neither is refuelling necessary, while the plant can be left unattended for long periods. This type of plant is noiseless and perfectly safe in unskilled hands, while in addition to its normal use for providing light it can be used for charging wireless accumulators, and keeping car batteries in condition, and there is also the added attraction that even if a mains supply of electricity *is*

available a wind-driven generator makes one independent in cases of emergency.

Equipment Required.

Briefly the plant consists of a 12-volt 100-watt
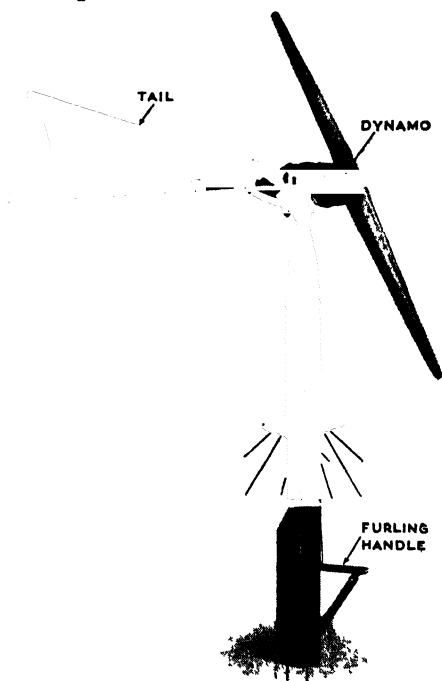
FIG. 1.—WIND-DRIVEN LIGHTING PLANT IN NORMAL RUNNING POSITION.

dynamo, direct-coupled to a twin blade propeller, which together with the headstock, tail, etc., are mounted on a wooden mast or steel tower. The dynamo armature is mounted on ball bearings which

ensures that the propeller will revolve even in light breezes. The dynamo is arranged to charge two 6-volt batteries of the car starter type rated at 130 ampère-hours each, in a manner similar to car practice, the batteries of course feeding the lighting circuits. The
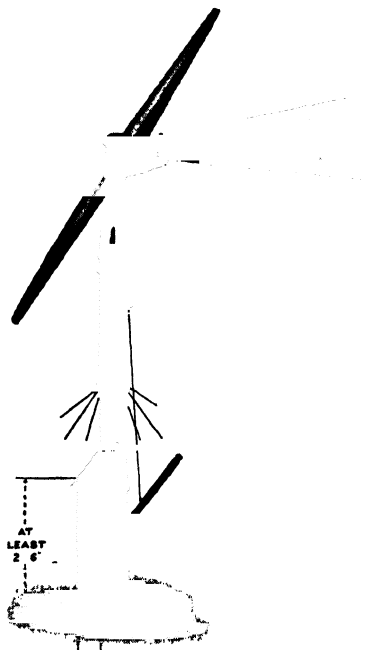
FIG. 2.—POSITION WITH FAIL FURLED.

makers recommend that not more than six lamps be used, three rated at 24 watts, and three at 6 watts.

A fuse is provided, connected in the dynamo field circuit. This is housed under a knurled thimble which is screwed into the commutator end-plate of the

dynamo. Connected between the dynamo and battery is a cut-out similar to those used on cars, which allows current to flow from the dynamo to the battery only. The cut-out closes when the dynamo is running fast enough to charge the battery, and opens when the dynamo speed is low, thus preventing current from flowing from the battery through the dynamo windings.

Choice of Site.

The site for the mast carrying the propeller and dynamo should be carefully chosen in order to get the best results. It is essential that the airflow to the propeller is uninterrupted by trees, buildings or other high objects, otherwise the plant will not operate satisfactorily. In order to ensure a good clearance for the propeller over the average house top, the mast must be at least 40 ft. high—in general the higher the mast the better the performance of the equipment. The mast must not be mounted on the roof or fixed to the chimney of a building, as under these conditions, the best results will not be obtained. While the mast should be clear of buildings the distance between it and the batteries should be kept as small as possible and should not exceed 50 yards.

Type of Mast.

The most convenient form of wooden mast is one of square section, approximately 4 in. by 4 in. It should be tapered at the top to 3½ in. by 3½ in. to take the top of the mast fittings provided by the makers; the length of the taper should be 10 in. A recess should be made at the top of the mast in order to allow the sliding member of the furling mechanism to move

freely. Before fitting the headgear on the mast, the tubular portion of the stand on which the furling mechanism operates should be greased. In addition, the headgear should be arranged so that the location for the tail is in line with the dynamo; this will ensure that the jaws of the furling lever will locate over the
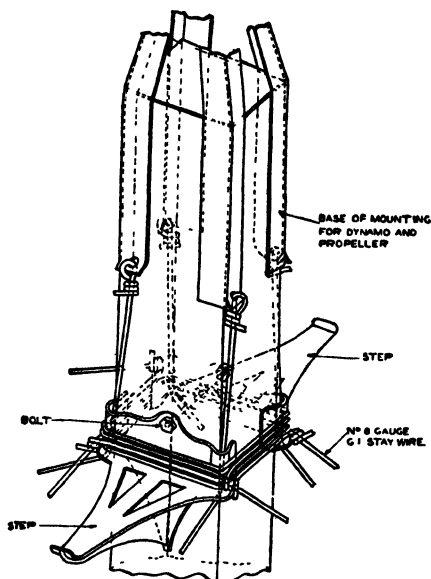
FIG. 3.—METHOD OF ATTACHING STEPS AND GUY WIRES.

flange on the stand. When securing the fittings to the top of the mast, the square plate in the headgear should fit squarely on the top of the mast, in order to prevent water gaining ingress to the end grain of the timber. Knocking the square metal band over the

tapering legs of the fittings as far as possible, will secure the headgear in position.

Two steel steps must then be bolted to the mast 36 to 40 in. below the top of the mast. Eight guy wires are required. Four guys should be brought up
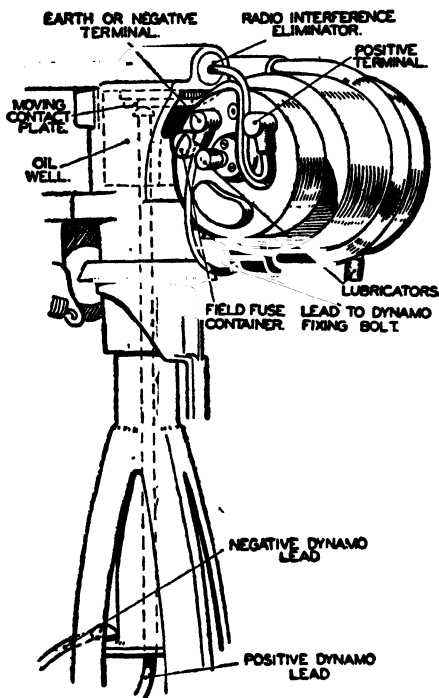
FIG. 4.—PARTICULARS OF WIRING TO DYNAMO.

through grooves in the steps and fastened through holes in the legs of the stand, while the other four should be wrapped round the steps. Deck spikes or other suitable fittings such as are used on telegraph

poles may be used as steps, and these should be fitted at intervals of about 18 in. on alternate sides of the mast before erecting.

Erecting the Mast.

The best method of erecting the mast is to sink a hard wooden post of the same or slightly larger section than the mast firmly into the ground. This post should project at least 2 ft. 6 in. above the surface of the ground. Fit one bolt through the bottom of the mast and post. By this means it is possible to assemble the complete headgear, with the exception of the propeller, on the ground, and then, by using the bolt at the bottom of the mast as a hinge, to erect the mast by pulling on some of the guy wires, while the other guys are used to steady and manipulate it. When this is completed, ensure that the mast is vertical by means of a plumb line and then fasten the guy wires firmly to suitable anchorage points.

It is essential to duplicate the main guy wires, that is, use two wires from each corner to the same anchorage point on the ground, also if desired, additional wires may be fitted half-way down the mast. Finally, the remaining bolt at the base of the mast has to be fitted to complete the erection.

Connecting up the Dynamo.

The negative cable terminal from the plate near the top of the headgear should be removed, and into it the end of a length of 7·064 cable should be soldered, after which the terminal is replaced and tightened. The cable should be run down the side of the mast, supported by means of staples. On reaching the
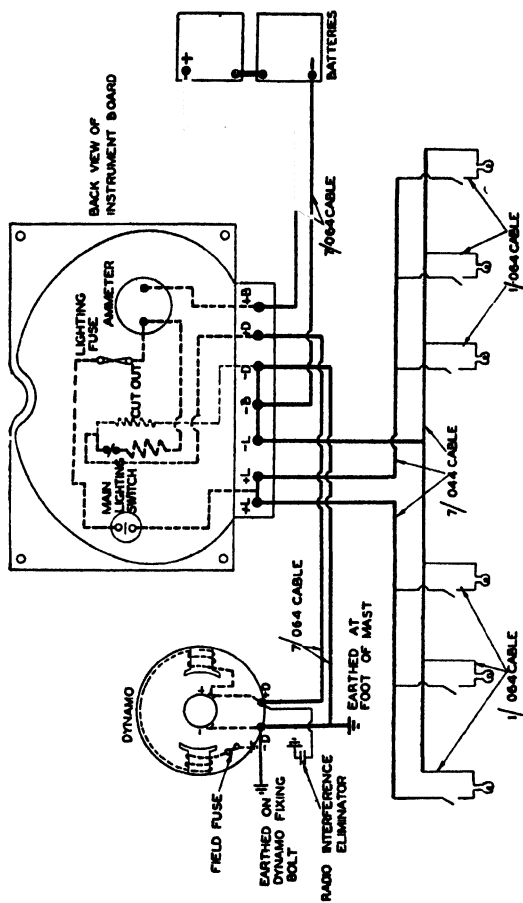
Fig 5 —Circuit Diagram of Wind-driven Lighting Plant

bottom of the mast, the cable should be carried along fencing, or on wooden stakes driven into the ground, and connected to the terminal marked "—D" on the instrument panel at the house or building to be illuminated. As a protection against lightning, a lead should be connected to the negative lead from the dynamo at the bottom of the mast and properly "earthed". The joint in the lead should be well insulated with tape.

A lead is provided for connecting the dynamo negative terminal to the bolt on the fixing band.

The positive lead should be soldered into the connector on the wire in the centre of the headgear, and supported by means of insulators, down the opposite side of the mast. This cable should be carried in the same way to the instrument panel and connected to the terminal marked "+D".

Finally the dynamo and headgear should be given a coat of paint as a protection against the weather.

An important point to remember is that the propeller should not be fitted until the whole of the erection, installation and wiring is completed, and the batteries connected, as this item actually constitutes the motive power.

CHAPTER VII

THE MAINTENANCE OF GENERATING SETS

SOME manufacturers, especially in the case of automatic sets, give a number of free visits for maintenance purposes in the first year after installation, and some have a subscription service after the first year. One can save considerably in expense by intelligent anticipation of a plant's need for attention.

Daily Attentions.

A daily visit to the engine room should be a habit. A check should be made of the water level in cooling tank or radiator, oil in the lubricator and bearing sumps where fitted, and of fuel in the service tank. Never allow any of these to get low, especially in the case of an automatic plant liable to run at any hour.

Weekly Attentions.

It is as well to set aside half an hour one day every week for a thorough clean up of the engine exterior and at the same time an examination of the tightness of all nuts and joints. A concrete block can soon be spoilt by the spilling of fuel or lubricating oil, and a dirty engine room is not likely to lead to good results from the engine.

The level of battery electrolyte should be inspected weekly and should not be allowed to fall below the

level of the plates. If any topping up is necessary distilled water only should be used, never acid, unless there has been a definite loss of electrolyte due to spilling and not to evaporation only. Ordinary tap water is not suitable, particularly if chemically softened.

Monthly Attentions.

Any grease nipples fitted usually require a charge
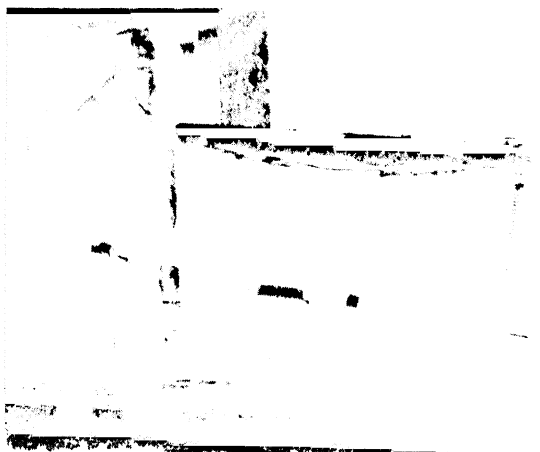
FIG 1—PORTABLE GENERATING SET
(*Stuart Turner, Ltd*)

about once a month, or screw-down type lubricators will need a turn.

The strainers fitted in the fuel tank, lubricator, fuel filter, or carburettor should be removed and cleaned thoroughly. This is best done with clean paraffin, and gauze strainers should not be wiped with a rag, as minute particles of cloth inevitably clog the small

holes. An old toothbrush is useful for the job and can be used also for removing scale from fuel tanks.

The exhaust system should be drained of any accumulation of oil and water that may be caught in pot silencers or bends. Not much oil should pass through an engine unburnt, and an exhaust with heavy, wet carbon deposits indicates at once that either too much lubricating oil is being given to the engine or combustion is incomplete.

If the exhaust system has been allowed to get badly carboned up it should be stripped down completely at the first opportunity and the pipes and silencer cleaned. Hard carbon can be chipped off in accessible places, but on pipes in long lengths or bends which are difficult to get at, carbon can be burnt off by heating the pipe over a brazier.

BATTERIES

Apart from the occasional topping up of the battery with distilled water attention should be paid to the condition of all connections, which must be kept clean and tight. If corrosion takes place the parts should be well cleaned and protected by the use of acid proof paint or vaseline.

Testing Condition.

The condition of the battery can be ascertained by its specific gravity or by the voltage reading of the cells.

The specific gravity falls as the battery is discharged, and should not be allowed to fall below 1·100 (the normal being about 1·240). The same cell should not be used each time for testing specific gravity, as a little electrolyte is lost with every reading.

Any test of the voltage of a cell or battery should be made on a closed circuit; that is, there should be a small discharge on, as readings on an open circuit are inaccurate. The fully charged cell has a reading of about 2·65 volts, and should not be discharged below about 1·85 volts. Records should be kept of readings recorded from different cells, as if there is found to be a considerable drop between readings either in voltage or in specific gravity the cell concerned must be examined.

Battery Charging.

Cells should never be allowed to stand discharged, and if there is any doubt about their ability to last out until the next normal charging period they should be charged at once rather than risk over-discharging.

The normal charging current for a battery is given by the makers in every case, but as a rough guide it may be taken as being the figure obtained by dividing the rated cell capacity (at the 10-hour rate) by 7½. Thus a 75-ampère-hour battery has a charging rate of about 10 amps.

Where a lead-acid battery (to which the above remarks apply) is to be left standing for any length of time beyond, say, six weeks, an extended charge should be given prior to disconnecting the leads and a refreshing charge every 7–8 weeks. The cells should have a prolonged charge before being put into service again, and, of course, the usual attention of topping up must be paid regularly.

Replating of Batteries.

It will be found that the positive plates of a battery

have a shorter life than the negatives, and they may be renewed in preference to replating the complete battery. Roughly speaking, a set of negatives will outlast two sets of positives.

DYNAMO MAINTENANCE

Cleaning.

There is a tendency to neglect the dynamo in a lighting plant on account of its ability to run with the minimum of maintenance, but it must be cleaned periodically and kept free from damp or dust. A certain amount of carbon dust accumulates, and a pair of bellows forms the easiest way of cleaning this out.

Smoothing Commutator.

By removing the covers at the commutator end when the dynamo is running it can be seen whether there is undue sparking at the commutator. If there is, wipe the commutator clean with a soft rag: if sparking persists it may be a sign that the commutator is rough, and a piece of very fine glass-paper can be applied while the machine is running, the brushes being raised first in their holders.

When the commutator cannot be properly smoothed with glass-paper a commutator stone can be used in preference to the final remedy in really bad cases of turning down the commutator, which means removal of the armature and return to the makers or a competent firm of electricians.

Great care must be taken after stoning or applying glass-paper to blow away the dust. Between the

commutator segments there is mica recessed below the surface, and the surface groove must be kept clean by scraping with a suitable fine tool, taking care not to burr the segment edges or scratch the commutator.

Bedding-in Brushes.

The position of the carbon brushes is adjusted on the brush rocker by the makers and marked by them when the machine is tested. If the setting has to be altered the brushes must be rebedded, and this is also necessary when new brushes are fitted. Brushes should always be replaced before they get too short. Excessive wear is almost certainly due to the retaining spring pressing too tightly, and this is adjustable.

When bedding-in a brush, insert fine glass-paper, say No. 0, beneath the brush and hold the smooth side firmly and tightly against the commutator. Move the glass-paper in the direction of rotation of the commutator and repeat the operation until the brush has reached the curve of the commutator. Do not draw back the paper in the wrong direction of rotation.

If the dynamo is run without a load a little while after fitting new brushes it assists in forming a fine, smooth surface on the brushes; always be sure that brushes are free to slide in their holders.

Where any trouble is experienced with faulty windings or short-circuits internally the whole machine is best returned to the makers.

ENGINE MAINTENANCE

Two-stroke and Four-stroke Engines.

Internal-combustion engines are divided into two types, those operating on the 2-stroke and those on

the 4-stroke cycle. In the former case there is a power impulse from the engine at every crankshaft revolution, and in the latter type at every second revolution only. The arguments in the favour of each type and against the other are too numerous to be dealt with here, and it is assumed that the reader is familiar with the principles of operation. The chief difference so far as maintenance is concerned is in the

FIG 2.—SELF-CONTAINED AND PORTABLE COAL GAS OR PETROL A C. GENERATOR WITH OUTPUT OF 18 kW.
(*Crompton Parkinson, Ltd*)

methods of decarbonising, and adjusting the arrangements for the supply and scavenging of the fuel mixture.

Diesel, Petrol, and Paraffin Engines.

Both types are made to run on Diesel, petrol, or paraffin fuel—in the latter case the engine usually starts on petrol, changing over to paraffin when

warmed up. For such petrol/paraffin engines it is necessary to have a 3-way cock in the fuel system and change over to petrol for a few minutes before shutting down so as to fill the pipe with the lighter fuel, ready for starting.

The chief regular item of maintenance is the periodical decarbonisation of the engine, and this is the biggest overhaul that the ordinary user undertakes. Any more serious overhaul, such as involves fitting new bearings or crankshaft, is best left to a sound local firm or the makers.

Decarbonisation.

Apart from the primary purpose of removing the accumulation of carbon, decarbonisation gives an opportunity to examine the general condition of the engine and more particularly the state of the piston and connecting-rod bearings. The top overhaul, which consists of removal of the cylinder head only, is of no use in this direction, but a thorough decarbonisation involves removal of the piston or cylinder.

Preliminary Work.

Before starting the overhaul make sure that the battery, if one is used, is fully charged—some defect may come to light that will prevent your running the engine for longer than you expect.

Commence by draining off the water from the engine jackets by means of the 3-way cock in the bottom water pipe. Next disconnect all piping from the engine, i.e., water connections, fuel pipe to atomiser or carburettor, and exhaust pipe. Disconnect magneto

leads, if a petrol or paraffin engine, and mark with the cylinder numbers.

Removing Cylinder Head and Pistons.

Close directions cannot be given for the removal of the cylinder head owing to the different arrangements used, according as to whether the engine is a 2- or 4-stroke and, if the latter, fitted with overhead or side-by-side valves. The makers' instructions are usually explicit on the procedure to be followed. On the majority of lighting-plant engines a split large-end bearing is used in the connecting rod, and this bearing is dismantled by undoing connecting-rod bolts (usually secured by castle nuts and split-pins), accessible through crankcase doors. When the large-end bearing is loose the piston and rod can be withdrawn through the top of the cylinder.

On some smaller engines, however, a roller or needle-roller bearing is used with a built-up crank, and in this case, unless the bearing has to be renewed, the piston and connecting rod are left attached to the crank, and it is the cylinder which is removed.

Cleaning off the Carbon.

The cylinder head, piston crown, and top of the cylinder should now be thoroughly cleaned of carbon deposit and the piston rings removed for cleaning and for scraping out the ring grooves.

On a 2-stroke engine there will be carbon formed in the ports, which must all be cleaned well to prevent any obstruction to the free flow of gases. Correspondingly there will be carbon on the exhaust valves

of the 4-stroke, especially under the head, but also along the stem.

Piston rings require careful handling and are easily broken in fitting or removing. A good plan is to use strips of tin against the piston and slide the ring over these to its correct groove. When fitting new rings always try them in the cylinder first and also in the groove, to make sure they are not tight. Examine the edges for burns and touch up with a smooth file any rough places found. Rings should have no vertical movement in their grooves, but must be free.

Testing Connecting-rod Bearings.

Before reassembly examine the large- and small-end bearings. The former should show marks of even contact over as wide an area as possible. To test the points of contact rub the crankpin with red lead and fit the bearing, tightening up bolts to their usual amount only. Turn the engine over a few times and examine the bearing, when the points of bearing will be easily seen. If a white-metal bearing has to be scraped to improve its area of bearing, remember that a very fine scrape makes a big difference—it is not necessary to take out much metal.

A roller large-end bearing should be replaced as soon as it shows signs of slackness. There should be no up-and-down play, but some little side play.

In removing the gudgeon pin to replace a small-end bearing bear in mind that it is usually a driving fit in the piston and is also held by means of spring circlips or a setscrew. Great care must be taken on a small engine not to bend or strain the connecting rod by using undue force in taking out this pin.

In a 4-stroke engine it is usual to adjust and grind in the valves after decarbonising an engine. This is not a difficult process in itself, but may become so with some types on account of inaccessibility of the tappets for adjustment.

Valve-tappet Clearance.

The tappet clearances recommended for inlet and exhaust valves vary with different makes, but on a side-valve engine the inlet is usually given about 0·006 in. for a petrol type and the exhaust rather more, say about 0·008 in. On an overhead-valve engine these clearances are generally reduced a little. For Diesel types they are increased considerably, up to as much as 0·015 in. and 0·030 in. respectively.

When to Decarbonise?

The frequency with which a plant requires decarbonising must depend on its use, naturally, but on an average the ordinary battery-charging set on house supply will need this attention at least twice a year. An automatic or direct-running set may require it three or even more times, according to the load conditions. A petrol or paraffin engine is the better for being decarbonised every 400–500 hours and a Diesel every 1,000–1,200 hours, but load conditions may vary these figures considerably.

RUNNING TROUBLES AND REMEDIES

Petrol-engine Starting Troubles.

The most fruitful sources of starting troubles on a petrol or petrol/paraffin engine are the magneto and carburettor, and most people have had sufficient

experience with car or motor-cycle engines to recognise and diagnose the usual faults.

If on turning over the engine by hand there is no sign of firing taking place the ignition system is naturally suspect. Sparking-plugs should be removed in turn and placed on the head with the H.T. leads attached. Turn the engine over smartly and see if there is any spark at the plug points. The spark should be strong and blue in colour. If there is a spark the engine will nearly always fire, even though the timing has slipped.

Should there be no spark at the plugs, examine the magneto and leads for an earth or poor connection. A cracked distributor cover or perished rubber can cause a short. Check the magneto contact-breaker points gap—it varies between 0·012 and 0·020 in. on different makes—and see that the points are clean and dry.

It is a common fault to have the gap on the sparking-plug points too wide: this should be about 0·025 in.

Assuming that a spark can be obtained at the plugs, the carburettor should be examined next. Condensation is always going on in the petrol tank, and a fair amount of water finds its way to the float chamber. It can easily be removed, of course, but until it is discovered it will cause a complete stop, or at best very irregular running. The jet may be choked by scale from pipe or tank—never clean a jet with wire: it can be done by washing in petrol and blowing.

An engine will run a long time with its filter almost choked with fluff and dirt, but this will cause trouble eventually, so it is best to keep the filter clean before a stoppage occurs.

Two-stroke engines are prone to give trouble in starting if flooded with petrol, and it is often necessary to drain out the carburettor and start again without flooding at all.

When a petrol engine runs with continual misfiring the carburettor probably needs adjustment, as this is a sign of too weak a mixture or of a choked fuel supply. Back-firing and spitting in the carburettor are usually due to valves being stuck or the timing wrong. Regular misfiring is also a sign of defective ignition system or oiled-up plugs.

Diesel-engine Starting Troubles.

Most Diesel troubles begin in the fuel system, and on a failure to start, the first examination should be directed to seeing that fuel is getting to the pump and thence to the atomiser. An air lock may cause a stoppage, or the pipe or filter element may be choked. If fuel is reaching the pump but not the atomiser, the pump plunger is probably suspended in its sleeve, due to some foreign matter, and this must be removed by dismantling the pump and cleaning the plunger and sleeve in clean paraffin. Alternatively, the delivery valve may be stuck up and the spring broken, which of course means a replacement.

If the trouble is not situated in the fuel system it is probably due to lack of compression, which may be due to a leaky cylinder-head joint or a decompressor valve remaining open.

The atomiser is liable to become choked; to examine this take out the atomiser and reconnect to the fuel delivery pipe. Then operate the fuel-pump priming handle, if such is fitted, or alternatively turn the engine

over smartly and observe the spray. This should be in the form of a fine mist, sharply ejected and cut off clean without any dribble from the nozzle. Where the nozzle holes are choked with carbon they must be cleaned out with the special pricker provided, and on no account must any coarser instrument, such as wire or a needle, be used.

Although seldom used by a private owner, any commercial installation should have available a testing set for atomisers. This consists of a hand-operated pump with pressure gauge mounted on the delivery pipe and connection for the atomiser. The setting of the latter for pressure can then be easily adjusted to the correct figure.

If there is not a clean cut-off at the finish of injection the probable cause is the atomiser needle being damaged in some way and sticking. This must be cleaned with paraffin, and the seating may require gently regrinding with a little metal polish. It is essential when working on either atomiser or fuel pump that the paraffin used is absolutely clean and that parts are not wiped with rag, which may mean bits of fluff sticking.

No adjustments beyond the simplest should be attempted by the user on either fuel pump or atomiser, as they are finely adjusted, and when possible it is best to carry a spare atomiser for emergencies so that the faulty original can be returned to the makers for overhaul.

Inability to get Full Load.

Inability to get full load from a set may be due to falling off in engine power or to dynamo trouble. A

common minor instance of the latter is in brushes sticking in their holders or being unduly worn.

Engine power invariably falls off when decarbonisation is overdue, and the same symptom shows if the exhaust piping is badly carboned up. Check this by running the engine with the exhaust pipe disconnected. If any obvious improvement results in engine output and speed it can safely be assumed that back-pressure is being caused by the choked pipe or silencer.

An engine may also show a loss of power on account of poor compression, when new rings for the piston may improve the running, at any rate temporarily, or an oversize piston may be fitted with a rebored cylinder or liner.

Obviously loss of power following on adjustments to the timing, carburettor or fuel pump, atomiser, or ignition system is in a different category, being evidently due to maladjustment.

It is as well to take an engine's speed occasionally if a revolution counter is available, but if speed is below the rated figure do not start altering governor springs unless full power is not being obtained. If, on the other hand, speed is too high it should be reduced, and if power is then too low look for the cause elsewhere.

Overheating.

Overheating is frequently accompanied by falling off in power, and almost invariably by excessive fuel consumption. Local overheating of bearings is caused by malalignment, tightness, or poor lubrication, and must be seen to at once, or a new bearing will soon be needed. Inadequate lubrication will result in seized

pistons and scored cylinders, but a seizure may result despite proper lubrication with a new engine or one in which a new piston or rings have been fitted. Any tight spots in the cylinder should be eased with a smooth oilstone and especial care taken to see that rings fit easily with a gap when tried in the working bore.

A common cause of the cylinder head and jacket overheating is the formation of scale in the jacket and passages as a result of hard water having been used. Rain-water should be used for making up the tank.

Removal of Scale.

From some parts of the engine jacket the scale can be chipped off, but in others a solvent is essential. There are various solvents marketed of proprietary makes, but if none are available a weak solution of hydrochloric acid can be used (about 20 per cent.). In any case, the engine should be left to cool down after running before draining the jackets and refilling with solvent or acid solution. The solution should be left in the engine jackets for about four hours and then drained off and the jackets thoroughly flushed prior to refilling with soft water. Where the acid solution is used it can easily be seen when it has penetrated the scale and is working on the metal beneath. Naturally it is important that no trace of acid remains, so that if a run through of water can be arranged under pressure this should be done.

Exhaust Smoke.

The exhaust smoke forms a very good indicator as to the state of the engine, and should be watched both

when the engine is started up first and after it is well warmed up. There is certain to be some fairly heavy smoke on starting, but this should soon give place to light-grey or bluish smoke, or even a clear exhaust. Continuous heavy smoke shows overloading, excess lubricant, or slack pistons, and should be dealt with at once.

Conclusion.

Finally, it should be borne in mind that with the prime mover, as with every other portion of a private generating plant, a periodic routine inspection may be the means of avoiding breakdown or failure at a time of vital emergency.

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